ABSTRACTS

For more information, please visit the FINSKEN Web site at:

http://www.vyh.fi/eng/research/projects/finsken/ (in English)

http://www.vyh.fi/tutkimus/ilmakeha/finsken/ (in Finnish)

INTRODUCTION TO FINSKEN AND PURPOSE OF THE SEMINAR

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The FINSKEN Project

FINSKEN (Developing Consistent Global Change Scenarios for Finland) is a project in the Finnish Global Change Research Programme (FIGARE), jointly funded by the Academy of Finland (67%) and the Ministry of Transport and Communications (33%). The project is co-ordinated at the Finnish Environment Institute (SYKE), and comprises six research groups working in four institutes: SYKE (2 groups), the Finnish Futures Research Centre, Turku (FFRC), the Finnish Meteorological Institute (FMI - 2 groups) and the Finnish Institute of Marine Research (FIMR).

FINSKEN aims to develop up-to-date projections of changes in environmental and related factors in Finland during the 21st century and beyond. Such changes are commonly described as "global changes" because many of the driving factors of change, as well as the changes themselves, are global in scope, even if their impacts are observed locally. Global changes may affect human health and well-being, natural ecosystems and biodiversity, water quality and availability, food and fibre production and a range of other economic activities. In order to judge the likely future implications of these changes in Finland, and to explore options for reversing or slowing ongoing trends, it is necessary to improve our understanding of current trends and to project them into the future. Since most environmental changes are strongly linked to socio-economic driving factors, it is necessary first to investigate how these may change in the future. Given the enormous uncertainties associated with estimates of future human behaviour, it is impossible to predict the future with any confidence; rather it is customary to construct "scenarios", which describe plausible future conditions.

The scenarios being developed by the different research groups and presented at this seminar include:

- Socio-economic and technological scenarios, including population, economic growth, and energy use (FFRC - Kaivo-oja and Willenius, 2001)
- Atmospheric composition scenarios, including tropospheric ozone, sulphur and nitrogen compounds (FMI - Laurila *et al*., 2001)
- Acid deposition scenarios (SYKE - Syri *et al*., 2001)
- Climate scenarios, including temperature, precipitation, atmospheric circulation and, in addition, carbon dioxide concentration (FMI - Tuomenvirta and Jylhä, 2001)
- Sea level scenarios (FIMR - Kahma *et al*., 2001)

One of the key objectives of FINSKEN is to develop scenarios that are mutually consistent. This requires that all scenarios should be based on the same underlying socio-economic driving factors. To address this need, FINSKEN has adopted, where possible, the socio-economic and technological storylines developed by the Intergovernmental Panel on Climate Change (IPCC) for its Special Report on Emissions Scenarios (SRES). These storylines are also described at the seminar (Nakicenovic, 2001). Finally, a closely related set of scenarios of stratospheric ozone and ultraviolet radiation for Finland, which are being developed in a parallel FIGARE project called LOUVRE, are also presented at the seminar.

With a given set of socio-economic assumptions it is possible to calculate a range of plausible scenarios of emissions of greenhouse gases and aerosols into the atmosphere. Similarly, for a given emissions scenario, it is possible to estimate the concentrations of gases and aerosols in the atmosphere, their effect on the radiation balance of the Earth, and their effect on the climate and, subsequently, on sea level. Since projections are uncertain at each link of the chain, sets of scenarios need to be developed that represent the range of uncertainty at each level.

Purpose of this seminar

Though it is well established that environmental change can affect (and may already be affecting) a wide range of natural systems and human activities, there are still large gaps in knowledge about the likely future magnitude and rate of such impacts, as well as the adaptive capacity to ameliorate negative impacts or to exploit positive impacts. Scenarios of future environmental change in Finland could be useful for assessing possible impacts on sectors or systems that include:

- Forestry and agriculture (e.g., regional suitability, growth, yield, quality)
- Terrestrial and aquatic ecosystems (e.g., biodiversity, peatlands, fisheries)
- Water resources (e.g., quantity, quality)
- Energy supply and demand (e.g., hydro, wind and solar power, space heating and cooling)
- Insurance and financial services (e.g., damages by flood, wind, hail, ice, pollution)
- Tourism and recreation (e.g., snow conditions, lake/sea water quality)
- Transport and communications (e.g., road, rail, air, shipping)
- Infrastructure (e.g., housing, coastal protection)

However, the specific scenario needs of different interest groups are likely to differ between their sectors of activity and their areas of responsibility. This is evident from an examination of the responses to a FINSKEN questionnaire on this topic (reported at the seminar - Bärlund and Carter, 2001). The seminar is designed to follow-up the questionnaire with a more detailed analysis and discussion of scenario requirements.

The seminar has three main goals:

1. To describe the methods being used by FINSKEN researchers to develop scenarios of global environmental change for Finland.
2. To obtain feedback from representatives of the private sector, public sector, non-governmental organisations and researchers concerning their requirements for global change scenarios.
3. To present preliminary scenarios for discussion.

Timed at the mid-point of the project, the seminar provides an opportunity for a direct interchange of information between FINSKEN researchers and potential users, offering scope for researchers to modify their workplans to better accommodate the expressed scenario needs of the user community.

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DRIVERS OF ENVIRONMENTAL CHANGE: THE NEW IPCC SCENARIOS

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Abstract

The Intergovernmental Panel on Climate Change (IPCC) decided at its September 1996 plenary session in Mexico City to develop a new set of emissions scenarios to be used in its future work. The writing team formulated a set of 40 emissions scenarios. The scenarios are based on an extensive assessment of driving forces and emissions in the literature, six different integrated assessment modeling approaches, and an "open process" that solicited wide participation and feedback so as to reflect current understanding and knowledge about underlying uncertainties. The scenarios encompass different future developments that might influence greenhouse gas (GHG) sources and sinks, such as alternative structures of energy systems and land-use changes. They confirm that future greenhouse gas and sulfur emissions are the product of very complex dynamic systems, determined by driving forces such as population growth, socio-economic development and the rate and direction of technological change. As required by the terms of reference, the scenarios do not includes any future climate policies. Subsequently, it in its Third Assessment Report (TAR) the IPCC developed mitigation (post-SRES) scenarios that lead to eventual stabilization of GHG concentrations based on the SRES scenarios. The scenarios are available for use by wider scientific and policymaking communities for analyzing effects of future greenhouse-gas emissions and developing mitigation and adaptation measures and policies.

The new scenarios and their development process are documented in the Special Report on Emission Scenarios (SRES) published by Cambridge University Press in 2000 (Nakicenovic, et al. 2000), in special issues of *Mitigation and Adaptation Strategies for Global Change Journal* (Alcamo and Nakicenovic, 1998) and *Technological Forecasting and Social Change Journal* (Nakicenovic, 2000) and in a number of other scientific publications and web sites.

The scenarios are rooted in four narrative "stories" about future worlds that describe consistently the relationships between emission driving forces and their evolution. The four storylines are called A1, A2, B1 and B2. Each scenario is a quantitative interpretation of one of four future worlds. Thereby the storylines add context to complement the scenario quantifications. For each storyline several different scenarios were developed using six different modeling approaches to examine the range of outcomes arising from a range of models that use similar assumptions about driving forces. All the scenarios based on the same storyline constitute a scenario "family." The six models used are representative of different modeling approaches and integrated assessment frameworks in the literature. One advantage of a multi-model approach is that the resultant 40 SRES scenarios encompass the current range of uncertainties caused by the characteristics of different models that lead to variations in the calculated GHG emissions.

Altogether the 40 SRES scenarios fall into seven distinct groups – the three scenario families A2, B1, and B2, plus four groups within the A1 scenario family, A1, A1C, A1G, and A1T. The four A1 groups are distinguished by their technological emphasis – on coal (A1C), oil and gas (A1G), non-fossil energy sources (A1T), or a balance across all sources (A1). Rapid growth characteristic of A1 scenario family leads to high capital turnover rates, which mean that early small differences among scenarios can lead to greater divergence by 2100. Since the A1 family has the highest growth rates, it was selected to show this effect. This resulted six scenario groups that that span a wide range of uncertainty

Compared to the earlier IPCC IS92 scenarios, the recent global population trajectories are generally lower and the scenarios cover a wider range of energy structures. All scenarios describe futures that

are more affluent than today, and a narrowing of income differences among world regions is assumed in many of the scenarios. The report concludes that: (i) technology is at least as important a driving force as demographic change and economic development; (ii) all of the driving forces not only influence carbon dioxide emissions but also the emissions of other gases; and (iii) for most scenarios, global forest area continues to decrease for some decades, primarily because of increasing population and economic growth, but this trend is eventually reversed.

The SRES scenarios cover most of the range of carbon dioxide, other greenhouse gas and sulfur emissions found in the recent literature. In 2100 carbon dioxide emissions from energy sources range from about 3.3 to 37 GtC, similar to the range in IS92, and from land-use changes in 2100 from a sink of 2.5 GtC to a source of about 1.5 GtC, quite different from IS92. Some of the energy, and many of the land-use, scenarios show trend reversals where initial carbon dioxide emission increases slow down or peak and then gradually decline. Total cumulative carbon emissions from all sources through 2100 range from approximately 770 to 2450 GtC, slightly higher than IS92 at the upper end of the range. Like carbon dioxide, the anthropogenic emissions of methane and nitrous oxide span a very wide range by 2100. Annual sulfur emissions peak within the next decade or two and decrease until 2100 when they range from 11 to83 MtS. These scenarios are generally well below the IS92 range of about 50 to 225 MtS because of structural changes in the energy system as well as concerns about local and regional air pollution.

Similar future greenhouse gas emissions can result from very different socio-economic developments, and similar developments of driving forces can result in different future emissions.

There is no single most likely, central, or best guess scenario, either with respect to the SRES scenarios or to the underlying scenario literature. Hence, the driving forces and emissions of each SRES scenario should be used together.

In conclusion, while the special report did not assess the implications of these greenhouse gas and sulfur scenarios on radiative forcing and climate change there have been many scientists who have already used them in their climate models. These model calculations are described in IPCC TAR and show that the SRES emissions scenarios would result in projected increases in global mean surface temperature of about 1.4-5.8 degrees Centigrade by 2100 in contrast to those reported in the IPCC second assessment report of 1 – 3.5 degrees Centigrade. These higher projections are a result of the lower projections of sulfur emissions which tend to cool the climate, thus offsetting the warming effect of the greenhouse gases.

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SOCIO-ECONOMIC SCENARIOS FOR FINLAND

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Introduction

The main task of this research is to present and analyse future scenarios of Finnish population and economic development, as well as to apply technological and social foresight studies. In the study different scenarios are provided to incorporate a diverse array of factors including economic, demographic and technological elements. One of the major challenges of the study is to make explicit the correlations and the interactions between these fundamental systemic elements (economic activity, demographic structure, technological change, energy use and greenhouse gas emissions). Naturally, a lot of attention is paid to future-oriented analysis of the development of community infrastructure, especially in relation to energy production infrastructure.

Since the 1960s, scenarios have become a major concept and methodology in futures research. The very basic idea of scenario analysis is to analyse various sources of uncertainties and risks in different socio-economic contexts. Scenarios can be used in the planning and strategy formulation of global, domestic, and local climate change policies. This part of the FINSKEN project aims to operationalise at national scale for Finland the socio-economic scenarios developed globally for the Special Report on Emissions Scenarios (SRES) by the IPCC (Nakicenovic et al., 2001). The project seeks to interpret the SRES storylines (represented by so-called "marker" scenarios) for Finland using various modelling methodologies as well as expert team and other research evaluations. Multiple scenarios allow for multiple assumptions about the future, including potential changes in the structure of the relationships among the critical components of the national socio-economic system. Thus, multiple scenarios also allow decision-makers to formulate climate change strategies and test them in alternative future environments.

Research activites

The Finnish Futures Research Centre (FFRC) has focused on three types of research activities. First, some basic theoretical research concerning scenario techniques and methods have been conducted. Second, empirical analyses concerning the Finnish economy have been carried out in order to conceptualise the starting points of socio-economic scenario analyses. Third, and the major effort, concerns scenario modelling of the SRES marker scenarios for the case of Finland. In order to operationalise the IPCC scenarios for the Finnish economy, a long-run scenario accounting model is being developed. A working version of model is ready and preliminary socio-economic analyses can be presented on the basis of model results.

The basic ideas of the long-run scenario accounting model are the following:

1. The model is based on the traditional Social National Accounting (SNA) system and includes sectoral energy statistics.
2. The model gives flexible possibilities to evaluate potential long-run socio-economic changes in the Finnish economy.
3. An accounting model offers opportunities to construct alternative variants of the baseline IPCC scenarios (A1, "Global Markets", A2 "Provincial Enterprise", B1, "Global Sustainability" and B2, "Local Stewardship" as some British researchers define the scenarios).
4. The model provides options to vary the following policy variables: (1) sectoral economic growth, (2) the rate of technical progress in sectoral energy production, (3) the productivity of labour in different sectors of the econony, and (4) the sources of energy.
5. The model is an integrated greenhouse gas emissions accounting system.
6. The accounting model provides empirical results concerning policy relevant transition paths of the Finnish economy. The transition paths cover the historical and future period 1975/1980-2100.

A scenario accounting model demonstration

Because of strict time constraints, a demonstration of accounting model results is limited to two operationalised IPCC scenarios for Finland: socio-economic scenarios for the Finnish economy are presented on the basis of first, the A1 scenario, and second, the B1 scenario. Some variations of the A1 scenario family are also presented. In order to demonstrate the analytical power of the accounting model, two variations of the long-run Global Markets scenarios are provided for Finland. In the first scenario, Finland solves climate change policy problems by building a new, fifth nuclear plant. In the second scenario, Finland builds no new nuclear plants during this century. In a third scenario four nuclear plants are introduced. Illustrative results of the study will be presented. The preliminary empirical results are presented in the form of trade-off transition path analyses.

Transitions are transformation processes in which society changes in a fundamental way over a generation or more. Although the goals of a transition are ultimately chosen by society, governments and private companies can play a role in bringing about structural change in a stepwise manner. Their management involves sensitivity to existing dynamics and regular adjustment of goals to overcome the conflict between long-term ambition and short-term concerns. The model developed here provides new perspectives for thinking about potential socio-economic transition processes in the Finnish economy, in the context of climate and energy policy alternatives.

These trade-off transition analyses of the FINSKEN study provide new results concerning socio-economic policy choices for futures development. In the current form of the model, it is possible to account for the following policy-relevant variables: GDP, population, energy demand, CO_2 emissions, labour demand, labour reserve, GDP/capita, GDP/labour reserve, CO_2/capita, CO2/energy demand, energy demand/GDP, labour demand/GDP and GDP/labour, energy demand/capita, energy demand/labour. Additional variables (especially other greenhouse gases and socio-economic variables connected to land use) will be added to the model later.

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DEVELOPMENT OF FINSKEN CLIMATE SCENARIOS

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Introduction

The aim is to develop state-of-the-art projections of changes in climate and atmospheric CO_2 concentration in Finland for this century. The main tasks can be summarised as: (1) Determination of current climate trends in Finland. (2) Development of scenarios of climate and carbon dioxide. (3) Provision of information and guidance to users of climate scenarios.

Climate trends

Climate trends in Finland in relation to natural climate variability will be determined from observations. However, data homogeneity need to be studied before reliable estimates of trends can be calculated.

Scenarios of climate

The development of climate and atmospheric CO_2 concentration scenarios will be based on IPCC (Intergovernmental Panel on Climate Change) Special Report on Emission Scenarios (SRES) (Nakicenovic et al. 2000). From these SRES scenarios future CO_2 concentration can be resolved (Fig. 1a). Accounting for uncertainties in the climate sensitivity and using all 35 SRES scenarios gives a large range for the global mean temperature change by 2100 (from 1.4ºC to 5.8ºC, see Fig. 1b).

Figure 2 shows interim climate characterisations for Finland based on preliminary SRES scenarios and Atmosphere-Ocean General Circulation Model (AOGCM) simulations in IPCC Data Distribution Centre (IPCC-DDC 2000). New AOGCM simulations forced with SRES scenarios will supersede them in the final phase of FINSKEN. In the meanwhile, a scaling method (Hulme and Carter 2000) has been used to estimate the range in regional climate projections arising from the uncertainties in emissions and climate system response. Fig. 2 shows 4 scenarios: B1-low assumes low emissions and a low climate sensitivity; A1-mid and B2-mid are based on central estimates; A2-high assumes high emissions and a high climate sensitivity.

A typical AOGCM grid box resolution (200-300 km) may be too coarse for impact studies and analysis of extreme events. Dynamical downscaling of AOGCM simulations with regional climate models gives a more detailed (spatial and temporal) description of regional climate change (Christensen et al. 2001). Within FINSKEN a set of regional climate model results will be available at least for certain SRES scenarios (B2, A2) and time slices (2071-2100).

Information and guidance on scenarios

FINSKEN web pages provide general guidance and links to SRES scenarios. Detailed questions, e.g. concerning availability of climate model simulations, should be directed to the authors.

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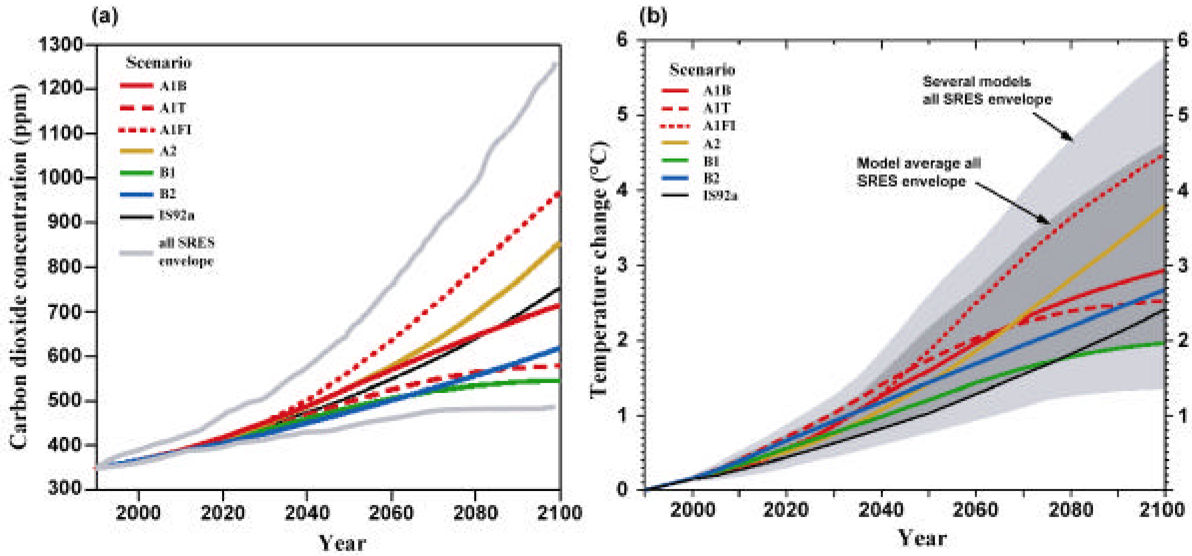

Figure 1: **Atmospheric CO_2 concentration and global temperature change scenarios in the IPCC Third Assessment Report** (IPCC-WG1 2001). (a) The CO_2 concentrations projected from the six illustrative SRES scenarios (Nakicenovic et al. 2000) along with a former IPCC scenario (IS92a). (b) The corresponding global mean temperature changes projected with a simple climate model. Besides CO_2, emissions of other gases and aerosols were included. Grey curves in (a) shows the range arising from uncertainties in carbon cycle modelling. Dark shading in (b) shows the range using a central estimate of climate sensitivity and the full range of 35 SRES scenarios in the simple model. Light shading in (b) shows the range from using all SRES scenarios and a range of climate sensitivities (taken from AOGCMs) in the simple model.

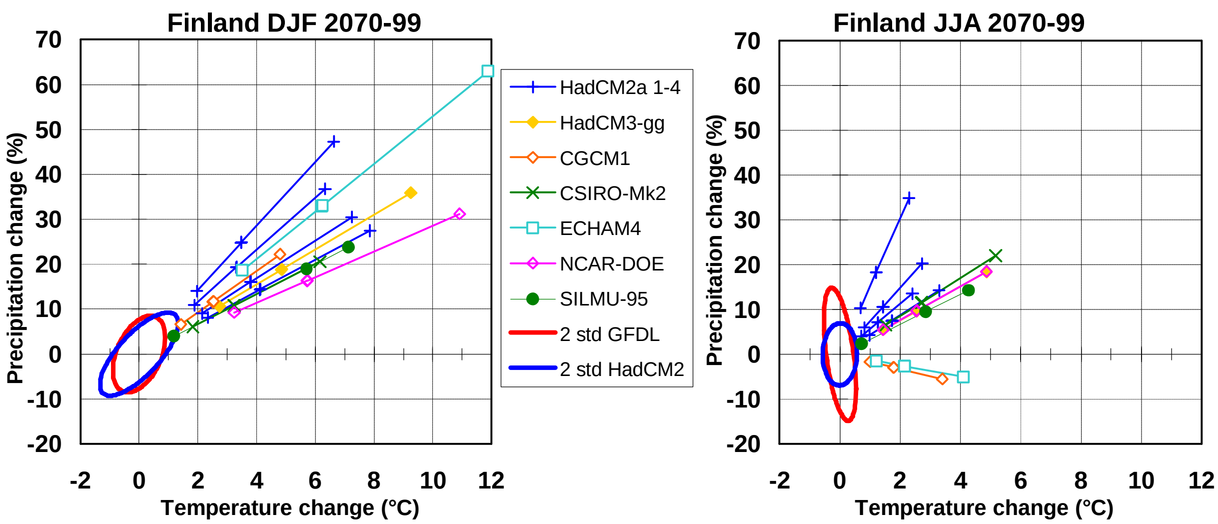

Figure 2. Preliminary scenarios on temperature and precipitation change in Finland Scatter plots showing December-February (DJF) and June-August (JJA) temperature and precipitation change by the 2080s (2070-99) relative to the 1961-90 in Finland. Four scenarios described in text are in each line outward from the origin: B1-low, B2-mid, A1-mid, A2-high (B2-mid and A1-mid are almost on top of each other). AOGCM simulations are from IPCC-DDC. Also a set of former climate scenarios for Finland are depicted (SILMU-95). Ellipses show the multi-decadal variability simulated by the GFDL and HadCM2 AOGCMs.

SEA LEVEL SCENARIOS

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Globally the probable scenario of climate change means an accelerated rise in the sea level. Along the coasts of Finland, however, the postglacial rebound lifts the land by an amount of 30 cm to 1 m per century. On the coasts of the Gulf of Bothnia the land uplift will compensate for the accelerated sea level rise predicted by the mid estimate of the business-as-usual scenario. On the Gulf of Finland the predicted relative rise in the sea level by the year 2100 will be from 0 to 11 cm. This means that the most probable scenario has minimal consequences even on the most vulnerable part of the Finnish coast.

On the other hand the upper limit of the accelerated sea level rise will be compensated by the land uplift only on the Bothnian Bay and around the northern half of the Bothnian Sea. On the Gulf of Finland the predicted rise will be from 20 cm to 50 cm. The consequences of this rise even in the most vulnerable part of Finland are somewhat less severe than elsewhere in the world because the sea will only inundate areas that have been above water for less than 200 years.

Because the most probable rise of global sea level has minimal consequences even in the most vulnerable part of the Finnish coast, the other implications of climate change for the sea-related risks are of greater importance.

Besides the rise in the global sea level and the land uplift, the water balance plays an important role in the mean sea level of the Baltic Sea. The variability of the amount of water in the Baltic Sea is about 370 km^3, which corresponds to a change of one meter in the sea level. Variability on the scale of months is dominated by the exchange of water through the Danish Straits and this variability does not even out on an annual scale. The annual mean sea level may deviate by 10 cm from the long-term moving average.

We have shown that the long term changes in the water level of the Baltic Sea are connected with large-scale meteorological systems, in particular the North Atlantic Oscillation (NAO). The correlation between the 15 year averages of NAO and the mean sea level is high and can explain most of the deviations from the linear trend. This allows land uplift rates to be redetermined with a higher accuracy than has been possible in the past.

During the last quarter of the 20th century the mean sea level of the Baltic Sea has risen by about 5 mm per year, of which over 3 mm per year is related to the water balance of the Baltic Sea and the rest to the rise in the global sea level. The 5 mm per year rise can be well predicted by NAO.

The annual variability of the sea level, expressed as a standard deviation, has varied statistically significantly. The overall trend during the 20th century is increasing. The same applies to the annual maximum sea level as well as to the probability distribution of the sea level. These changes are also correlated with NAO, but the relationship is less clear.

Historically, the land uplift on the Finnish coasts has created an interest in accurate sea level measurements. Systematic measurements begun in 1858, and in 1933 the construction of a dense network of 13 tide gauges along the coast was completed. Where possible, they have been founded on the solid bedrock, and these ones are especially reliable for monitoring long-term changes. The oldest of the tide gauges, in Hanko, has operated from 1887. The land uplift as well as the annual variability can be determined with high accuracy from our data.

Three types of scenarios are of interest here and will be calculated by FIMR:

1) The scenarios for the mean sea level along the Finnish coast.

These scenarios are important for eg. shipping (waterways, harbours), water exhange in the bays, and the evolution of wetlands.

The calculations will be based on the scenarios for the global mean sea level rise, land uplift, and the NAO index. The scenarios for the global mean sea level rise are obtained from the latest report of the IPCC. The scenarios for the NAO index will be obtained from the climate scenarios prepared by the FINSKEN subgroup of the Finnish Meteorological Institute. The land uplift rates will be recomputed by the FIMR group.

2) The scenario for the maximum sea level.

This scenario is used to evaluate the risks for buildings, harbours, roads and bridges. The scenario is important for eg. city planning and estimating erosion of the shoreline.

These calculations will be based on the scenarios for the global mean sea level rise, land uplift, the NAO index, statistics of the annual variability and a trend forecast for their change in the future.

The method is to calculate the probability distribution of the sum of the above components. The probability distributions for the global mean sea level and NAO scenarios are formulated to reflect their uncertainties.

3) The scenario for the sea level variability.

Scenarios for short period sea level variability will be calculated on the basis of the trends and variations obtained in the first part of the study. The probability distributions obtained will be added together with the distributions of the mean sea level to obtain the probabilities of the sea level exceeding a certain height in the future.

Preliminary scenarios for mean sea level and extreme sea level values have already been calculated. Studies about the relation between Atlantic climate and sea level variability are going on. Our next task will be to incorporate the proper scenario for the NAO index and to refine the sea level scenarios calculated.

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SCENARIOS OF ACIDIFYING EMISSIONS AND DEPOSITION

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Introduction

Within this task of the FINSKEN project, short- and long-term scenarios of acidifying emissions and deposition are investigated and developed. Global energy scenarios are reflected in changing emission quantities in Europe. The regional scenarios are compared to Finnish national estimates to highlight the consistency and differences of different approaches to their derivation. The emissions scenarios of sulphur, nitrogen compounds and volatile organic compounds in Europe lead to different patterns of atmospheric concentrations and deposition, calculated with both long-range and mesoscale models available at the Finnish Environment Institute (SYKE) (Syri et al. 1998). This work is carried out in co-operation with the Finnish Meteorological Institute (FMI - Laurila at al. 2001). The pollutant exposures and loads are compared to ecosystem critical thresholds, derived and updated at SYKE for the UN-ECE/CLRTAP framework (Johansson, 1999).

Short-term scenarios

Recent emission reduction agreements within the UN/ECE (UN/ECE, 1999) and the EU are expected to reduce considerably the emissions of acidifying substances in Europe by the year 2010. These reductions will be reflected in Finland as substantial decreases of areas at risk of acidification. The possible implementation of the Kyoto protocol in Europe would induce further reduction of acidifying emissions as a result of energy saving and shifting towards less sulphur-intensive fuels (Syri, 2001).

As part of the preparation of the Finnish climate strategy coordinated by the Finnish Ministry of Trade and Industry (Ministry of Trade and Industry, 2001), work has been carried out at SYKE by the research team to estimate the environmental effects of the Finnish climate strategy. Three alternative scenarios were derived up to the year 2020: a ‘Baseline’ scenario, and two scenarios aiming at meeting the Kyoto emission targets (KIO1, KIO2). Table 1 presents the SO_2 and NO_x emission projections under these scenarios.

Table 1. Acidifying emissions with the energy scenarios of the Finnish Climate Programme (in kton SO_2 / NO_2 per year) (Hildén et al., 2001).

	Baseline		KIO1		KIO2	
Year	SO_2	NO_x	SO_2	NO_x	SO_2	NO_x
1998	90	252	90	252	90	252
2010	114	187	91	170	88	172
2020	117	182	79	160	84	164

The impact of these scenarios on the acidifying emissions, depositions and exceedances of critical loads have been evaluated at SYKE. In co-operation with the Finnish Meteorological Institute, the effects on the critical thresholds of ozone were also assessed. Table 2 shows the development of acidification critical load exceedances with the alternative Finnish energy scenarios, assuming the emissions from other European countries constant at the UN/ECE Gothenburg protocol ceilings (UN/ECE, 1999).

The results of the study indicated that without further technical measures Finland would not meet the international emission reduction commitments of the UN/ECE and the EU. The scenarios used in the preparation of the Finnish Climate Programme would have clear beneficial effects on the emissions of acidifying and ozone-forming pollutants and on the exceedances of critical thresholds. These data provide the best presently available knowledge about the likely future of Finnish GHG and acidifying emissions and thus form the background for further work on the SRES scenarios.

Table 2. Change in the total ecosystem area with deposition in excess of the ecosystem critical load ('Baseline' in 2010 ≡100) with the alternative scenarios.

	2010			2020		
	'Baseline	'Gas'	'Nuclear'	'Baseline'	'Gas'	'Nuclear'
Whole Finland	100	-4.4%	-4.5%	-1.6%	-7.4%	-5.2%
Southern and Central F.	100	-6.2%	-6.4%	-3.4%	-11%	-6.4%

Long-term scenarios

In the longer term, climate change will affect also the air transportation and transformation of acidifying compounds. Within the AIR-CLIM project of the EU 5th framework programme, an integrated analysis of the linkage between climate change and air pollution in Europe has been performed (Mayerhofer et al., 2001). As part of the project activities climate data calculated by the GCM ECHAM4 of the Max Planck Institute for Meteorology is used as input to the EMEP Lagrangian Acid Deposition Model (LADM). LADM is used to calculate transboundary acidifying pollution in Europe using national emissions estimates and the future GCM climate. The transfer matrices produced by LADM in the AIRCLIM project are used also in FINSKEN to estimate the effects of changing climate on the deposition fields of the SRES scenarios in Finland.

The long-term energy use and emissions projections of the IPCC Special Report on Emissions Scenarios have been implemented for use in this task. The work concentrates on the six marker emission scenarios of the SRES. The SRES scenarios are of global nature and thus provide data on a rather coarse level. Further work will include down-scaling of the scenarios for Europe in collaboration with the AIRCLIM project and comparison with shorter-term national and European energy and emission projections to ensure consistency and use of best available knowledge in the projections of depositions and exceedances of critical thresholds.

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SCENARIOS OF TROPOSPHERIC OZONE

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Introduction

In the troposphere, i.e. the lowest 10 km of the atmosphere, ozone is photochemically produced from methane, other reactive organic species and carbon monoxide in the presence of nitrogen oxides (NOx). All SRES emissions and atmospheric composition scenarios for the 21st century show increasing methane concentrations, leading to significant increase in the average tropospheric ozone concentrations (IPCC, 2000; 2001). The NOx concentrations are critical for the rate of photochemical ozone production. According to the SRES scenarios, NOx emissions are increasing rapidly in Asia, Latin America, and Africa, leading to high average and episodic ozone concentrations over these continental regions and long-range transport of polluted air to other parts of the world. As a consequence, tropospheric ozone concentrations also in unpolluted air masses in northern Europe will increase. Superimposed on these increasing tropospheric ozone levels, European precursor emissions will cause episodic high concentrations which may be detrimental to human health and vegetation. Ozone levels during these episodes depend on the scenarios of precursor emissions in Europe. The effect of global climate change on tropospheric ozone will be mostly due to increasing water vapour concentrations, resulting from the temperature increase, which will reduce the rate of ozone formation in photochemical processes.

The aim of this study is to develop future scenarios of air pollution concentrations and depositions in Finland that are consistent with the present understanding of future global and regional emission scenarios and the effect of climate change on atmospheric processes. An essential part of the research is to understand the emission – dispersion – deposition processes behind the past and present pollutant levels. Specific tasks of the study are: 1. Analysis of trends in surface ozone, 2. Development of scenarios of surface ozone, 3. Modelling and mapping the ecosystem-specific ozone dose, 4. Analysis of trends in acidifying air pollutants.

Methods

Analysis of past trends together with emission information and meteorological data is essential for the understanding of possible trends in photochemical pollution because Chemistry Transport Models (CTM) and emission inventories have always significant deficiencies. Observations in southern and central Finland show that ozone concentrations, especially in unpolluted air masses, have been higher during the late 1990’s compared to the early years of the decade. This is inconsistent with regional precursor emission inventories which should result in declining trends. One of the possible reasons for the discrepancy could be an increase of background tropospheric ozone concentrations.

The most important modeling tool used in the calculation of future ozone concentrations and surface fluxes is the photochemical model used in the EMEP-MSC-W at the Norwegian Meteorological Institute. This model will be used to study the effects of increasing tropospheric ozone concentrations and European emission scenarios. Changes in the climatic factors and meteorological patterns will be studied using the high-resolution climate change simulations conducted by the ECHAM model for the years 2040-2050. The simulated meteorological fields will be obtained from the European AIR-CLIM project and will be implemented to the oxidant model. Specific topics are the sensitivity of ozone exposure to the tropospheric ozone concentrations and to the temperature via changes in biogenic VOC emissions (Lindfors et al., 2000). To study the influence of future changes in the global tropospheric air composition in the European scale, the EMEP-model has been coupled to the global CTM at the University of Oslo which provides the boundary conditions for the regional model

(Jonson et al., 2001). This model system, including changes in tropospheric ozone concentrations, has been used to estimate the ozone concentrations near surface over Europe in 2010. The results will be compared with Nordic ozone scenario studies conducted at SMHI using MATCH-RCA1 modelling (Langner and Bergström, 2000) and global modelling by the Meteorological Office group in the UK (Collins et al., 2000).

This project also aims at detailed ecosystem specific ozone fluxes (Emberson et al., 2000). For that purpose we have actively participated in the development of the new dry deposition scheme of the EMEP model (Emberson et al., 2001; Tuovinen et al., 2001a). During the development the new module has been tested against direct ozone flux measurements over Finnish ecosystems (Tuovinen et al., 2001a;b), and is thus well adapted to the Nordic conditions. The new scheme calculates the stomatal functioning and the ozone uptake using environmental parameters. So far, the effect of humidity and increasing temperatures on the ozone uptake have been studied (Simpson et al., 2001). In the next phase, also other climate change related parameters, for example the soil moisture, will be investigated. This module is the basic tool in the calculation of ozone fluxes to the most important ecosystems in Finland for the FINSKEN scenarios.

Consistency with other FINSKEN groups is achieved by using global emission scenarios from the SRES report. European emissions will be provided by the FINSKEN group of the Finnish Environment Institute (FEI). The meteorological fields obtained from the AIR-CLIM project are the same as those used for calculating the transport matrices utilised by the FEI group. The regional climate simulation fields used in the MATCH-RCA simulations are the same as those used for the high resolution climate change studies by the second FMI FINSKEN group.

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RESULTS OF A QUESTIONNAIRE SURVEY OF POTENTIAL SCENARIO USERS

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Introduction

One of the underlying motivations in initiating the FINSKEN project was the perception that global change scenarios are potentially of interest to a wide audience, including policy makers, researchers, private industry, public utilities, the media, educational establishments and the general public. In January 2001 a questionnaire was sent to 588 persons representing the above-mentioned target groups of whom 175 persons (30 %) returned a completed form. The objective was to investigate the interest in obtaining global change scenarios for Finland and to gather information on the specific needs of potential future scenario users concerning socio-economic conditions, atmospheric composition, acidification and eutrophication, climate and sea-level. Knowledge of potential user requirements will be of valuable guidance to FINSKEN researchers in developing a set of scenarios that best meets the needs of the user community. The results may also be of wider interest to other researchers involved in scenario development.

Questions

The questions posed first addressed the different global changes covered by the scenarios (Question 1), and then investigated issues concerning the desired time horizon, temporal and spatial resolution, number and type, reasons for scenario use and likelihood and timing of scenario use (Questions 2-8, Table 1).

Table 1: Contents of the FINSKEN questionnaire in summary form

Q1A: socio-economic conditions	demographic changes, GDP, types of economic activities, trade transport infrastructure and technology, energy technologie and diet
Q1B: atmospheric composition	CO_2 concentration, S compounds, N compounds, tropospheric ozone, stratospheric ozone/UV radiation
Q1C: acidification and eutrophication	S deposition, N deposition, eutrophication of lakes, eutrophication of rivers, eutrophication of coastal waters
Q1D: climate	temperature, precipitation, wind speed, wind direction, humidity, radiation/cloudiness
Q1E: sea-level	mean sea-level, land uplift, maximum high water level
Q2: time horizon	up to 2010, 2025, 2050, 2075, 2100, beyond 2100
Q4: temporal resolution	sub-daily, daily, weekly, monthly, seasonal, annual
Q3: spatial resolution	regional average, national average, province, commune, river catchment, ecosystem type, regular grid, individual sites
Q5: type of scenario	single best estimate, several scenarios showing range of uncertainty, probabilistic scenarios, quantitative scenarios, qualitative scenarios
Q6: reason for scenario use	policy making, strategic planning, impacts research, other research, political lobbying, education, general interest
Q7: potential use of FINSKEN scenarios	yes, no, perhaps
Q8: date by which scenarios required	2001, 2002, later than 2002

Respondents were requested to express their need for each scenario attribute by answering either *yes*, *no* or *don't know*. Questions that were left unanswered were interpreted to mean that this particular question did not concern the person answering, and were recorded as *empty*. The need for other scenario types or attributes not listed could also be entered on the questionnaire as supplementary text.

Results

The 175 respondents were grouped according to the type of institution they represent and further according to three broadly and subjectively defined "fields of activity": development and utilisation of resources (**DEVUTI**), resource planning and policy (**PLAPOL**) and research (**RESEAR**). They were also classified in a different way, according to their “sector of interest”: agriculture (**AGR**), atmosphere (**ATM**), ecology and biology (**ECOBIO**), economy and social science (**ECOSOC**), environment (**ENV**), forest (**FOR**) and water (**WAT**).

The popularity of the five scenario types (Q1A-E) was first investigated using the groupings by field of activity. The percentage depicted is weighted by the number of persons in each activity group and by the number of sub-questions per question Q1A-E. Three of the five scenarios were regarded as similarly important by all activity groups: atmospheric composition, acidification and eutrophication, and climate (Figure 1). The socio-economic scenarios seemed to be of less interest to the research group and only the planning and policy group showed higher interest towards sea-level scenarios, though there were very few respondents from groups having an interest in coastal issues.

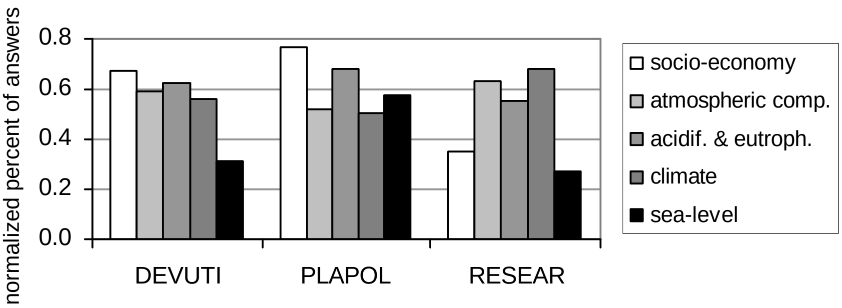

Figure 1: Interest of the activity groups in the five different scenario types

The second part of the questionnaire, **Q2-Q6** dealt with scenario attributes: time horizon, temporal resolution, spatial resolution type of scenario and scenario use. Certain general trends could be distinguished from the answers:

- The shorter the **time horizon** the greater the interest, with time horizons of up to 25 years the most popular, except among the RESEAR group, where there is also strong interest in longer time horizons.
- The lower the **temporal resolution** of scenario information the greater the interest, with preference shown for an annual or seasonal resolution. The exception, again, was for RESEAR where there is also some interest in scenarios at a daily or sub-daily resolution.
- Interest in scenarios with a supra-national or national **spatial resolution** was high among all groups, whilst information at smaller scales was of most interest to the PLAPOL and RESEAR groups.
- Of the different **scenario types**, the DEVUTI and RESEAR groups clearly favour quantitative over qualitative scenarios, though the PLAPOL group is more ambivalent. All groups appear to favour having a variety of scenarios, though many in the DEVUTI also opt for a single best estimate.
- **Reasons for obtaining scenarios** are closely tied to the composition of the activity groups, with the RESEAR group indicating a strong impact research application and less interest in strategic planning, policy making or politics. In contrast, the latter three applications are accorded a much higher priority by the PLAPOL and DEVUTI groups.

Overall, the questionnaire responses indicated that there is substantial interest in scenarios of global change for Finland across a wide cross-section of activity groups. In response to question 7, 61 % of the respondents thought that they or their organisation could make use of the FINSKEN scenarios and 32 % thought that perhaps they could use them.