NON-CO_2 GREENHOUSE GASES:

SCIENCE, REDUCTION POLICY AND IMPLEMENTATION

Report of the Fifth International Symposium, Wageningen, The Netherlands

30 June - 3 July 2009

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SCIENCE, REDUCTION
POLICY AND IMPLEMENTATION

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United Nations Intergovernmental Panel on Climate Change
Ministry of Housing, Spatial Planning and Environment in The Netherlands
United States Environmental Protection Agency
United Nations Food and Agricultural Organization
International Global Atmospheric Chemistry Panel of IGBP
European Commission
International Energy Agency Greenhouse Gas Research and Development Programme
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International Conference on Non-CO2 Greenhouse Gases 2009

Summary of the fifth international symposium on non-CO2 Greenhouse Gases in Wageningen 30 June to 3 July 2009

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Greenhouse gas concentrations in the atmosphere are still increasing despite the reductions in emissions reported by industrial countries to the Kyoto Protocol of the Climate Convention. Knowledge, not only on carbon dioxide emissions and concentrations but also on the less well known greenhouse gases is important in view of the climate negotiations.

The fifth international symposium on non-CO2 greenhouse gases (www.ncgg5.org) presented the scientific progress and discussed promising reduction strategies just before the Copenhagen summit in December 2009. The participants had a chance to test and exchange ideas in various workshops and a closing debate. It was concluded that many promising ideas still need a lot of stimulus and attention. Public-private partnerships were seen as a good vehicle to introduce mitigation measures in other countries.

General aim and scope of the conference

The NCGG conferences aimed at bringing together scientists, experts, policy and decision makers in the field of climate change with a view of supporting the development of efficient and effective technologies and policies aimed at decreasing the radiative forcing due to non-CO2 greenhouse gas and indirect gases and aerosols.

The scope of the conference was the science, the technology and the policy aspects of controlling non-CO2 greenhouse gas and precursor emissions, and the regulation at different policy levels. The fifth edition of this series of NCGG conferences covered the recent developments and added special emphasis on:

Scientific understanding of sources, sinks and atmospheric processes of non-CO2 greenhouse gases including precursor gases and aerosols.

Proposing mitigation options and reduction measures.

Implementation of policies and measures, both in the public and private sectors.

Introduction

The non-CO2 greenhouse gases are methane, nitrous oxide, HFC's, PFC's and SF6. They are part of the Kyoto Protocol basket of gases. Reductions of emissions of these gases contribute to the target of a 5% greenhouse gas (GHG) emission reduction worldwide. More than 200 experts from 20 different countries gathered in Wageningen to discuss the science and options to reduce emissions. The conference programme consisted of 127 presentations and 30 posters and again was larger than its predecessor ncgg4. In the opening address Jacqueline Cramer, Minister of the Environment in the Netherlands stressed the importance of the symposium in providing information on the science and policy of mitigation options.

Reduction CFC's successful

Guus Velders of the Planning Bureau for the Environment in his opening address illustrated that the Montreal Protocol has been more successful for the climate than the Kyoto Protocol, even up to six times as successful. It has been very successful in phasing out the production and use of ozone depleting substances. As these chemicals are also very strong greenhouse gases a substantial reduction in the global warming potential (GWP) was achieved.

Aerosols

For the first time attention was paid to aerosols at this symposium. Aerosols have a complicated relation with the energy balance of the atmosphere. White aerosols have a cooling effect, but black aerosols (soot) absorb heat and have a warming effect. Aerosols have a short lifetime in the atmosphere and thus a more local effect on the climate. The warming of the Earth would have been far more severe without the emissions of aerosols. Frank Raes, of the European Joint Research Centre in Ispra Italy, in an interesting plenary talk, made it clear that the increase in aerosols has gone unnoticed by the general public. By incomplete combustion of fossil fuels and of biomass in Africa, Latin America, and the far East (India, Indonesia and China mainly) our atmosphere is threatened. In El Nino years this is enhanced by the droughts and enormous fires in tropical forests and peatlands (e.g. in 1997 and 1998 in Kalimantan, Sumatra, Malaysia). Traditionally in the humid tropics agricultural plots are burned to clean from weeds, pests and diseases. Large areas are also converted to other crops by burning. Forest is converted to plantations by clear cutting and burning. The conversion of degraded forest to oil palm plantations is an example. Smoldering peat lands emit large quantities of soot, CO2, CO, NOx, aerosols and methane. The emissions from tropical burning in some years has been larger than the emissions from most OECD countries. Degrading peatlands in the tropics at the moment is more dangerous for the climate than the melting of the permafrost in the arctic tundras. In the climate negotiations compensation is proposed for countries to prevent deforestation and peat land destruction.

Methane

With 30 presentations and 10 posters methane was the hottest topic at the fifth ncgg conference. A special session on methane was organized because many new developments could be reported. The present interest in methane was fuelled by new uncertainties in the global methane budget when methane concentrations in 2007 started to rise again at a faster rate than expected. Emissions from tropical fires and

wetlands were suggested to explain the increase. However a small decrease in the methane sink by reaction with hydroxyl radicals in the atmosphere could do the same. It is as yet unclear which process is mainly responsible for the recent methane growth in the atmosphere. Jos Olivier presented new data on emissions from the emissions database for global atmospheric research (EDGAR). He reported an exceptional increase of the methane emissions in 2006 of 11% after a documented decrease of 13 Teragram methane in the preceding years by emission reductions from landfills, coal and sewage water treatment. Lori Bruhwiler in her plenary presentation analyzed possible causes for the increased growth of methane since 2006. According to concentration measurements at remote locations presented by Lori the increase in summer 2007 was mainly caused by higher emissions from arctic tundra as a consequence of higher than average temperatures and humidity. In 2008 the tendency was higher emissions from tropical peat lands.

These days the emission measurements at ground level can be compared with satellite measurements from SCIAMACHY, scanning imaging adsorption spectrometer for atmospheric cartography, an instrument on board the European Envisat. Detailed comparisons of top-down with bottom-up inventories resulted in more insight in individual sources of methane at spatial scales of 1 by 1 degree.

Methane emissions can be reduced at low costs. Most proposed options can be implemented and some are even profitable if methane is captured and sold to produce energy. This is possible with landfills, coal mining and sewage treatment. The reduction of methane from enteric fermentation in dairy cows is more expensive. But even there new results were reported by Wageningen University in cooperation with cattle feed producers.

Nitrous oxide

The emissions from soils are variable in time and space. Different participants from Wageningen presented models to estimate geographic explicit emissions for the Netherlands, Europe and the world using databases for land use, fertilizer use and soil management. Results were presented for three models, Initiator, Miterra and IMAGE. The results are compared to the official reporting to the Kyoto Protocol. At regional scales large differences are found although the totals match closely. This is related to the use of more detailed emission factors.

In most developing countries meat consumption increases with increasing population growth and affluence. Wilfried Winiwarter from the International Institute for Applied Systems analysis in Laxenburg near Vienna in Austria presented an expected growth of 30% in nitrous oxide emissions for 2030 in China as a result of a growing fertilizer use and a growing beef production.

Reactive nitrogen

A growing attention is given to the greenhouse gas budget of fertilized lands. An international and a European nitrogen initiative INI and NEU (NitroEurope) project has started to pay more attention to the adverse effects on land and water of increased fertilizer use. Arjan Hensen of ECN presented Nitrogenius, a user friendly computer game for scenario development to reduce nitrogen emissions from industry, agriculture and consumers. This game was presented and played during the conference by the participants. A separate workshop was organized for teams to seek

the optimal strategy of a country to reduce its nitrogen load to the environment. The International Nitrogen Initiative (INI) and NEU seeks partners for a future strategy for research on the challenge of reducing nitrogen in the environment.

HFC's and PFC's
HFC 125 is used as a cooling agent as an alternative for CFC. Global emission is estimated at 21 kton per year in 2007. At the moment an increase in concentrations in the atmosphere is measured of 16% per year. At the same time the other HFC's, PFC's and SF6 show a large growth. New estimates of SF5CF3 were presented at the conference. The global warming potential of SF5CF3 is 18000 times the potential of carbon dioxide. After the growth in concentrations during the sixties of the last century it now shows a leveling off.

Representatives of the semi-conductor industry reported the success of voluntary measures to reduce PFC's. The agreed reduction of 10% between 1995 and 2010 will be met. If the growth of the industry is taken into account an absolute reduction of 90% of emissions is effected. The key to success was intense cooperation between the semi-conductor industry and the specialized instrument builders.

Public private partnerships
Large reductions of greenhouse gas emissions are the result of cooperation of government with industry. Several programs were initiated for the support of ideas from industry. The methane to markets program of the US-EPA is running for many years already. New programs have started like the Asian Pacific Partnership to reduce PFC's from the aluminum industry. China with 80 smelters is the largest producer of aluminum and a good control mechanism for the production process can mitigate emissions. Recycling of aluminum is another option. Voluntary partnerships have been started in the USA to reduce PFC's, HFC 23 and SF6.

Detailed results of the conference will now be presented around the following themes and topics

THEME 1 sources, sinks and inventories of GHG
- Industrial processes, crop production and animal husbandry
- Emission inventories and high tier emission models
- Verification of emissions

THEME 2 monitoring and modelling of atmospheric composition of GHG
- General papers on methane
- Special methane session on recent changes
- Atmospheric processes
- Primary and secondary aerosols
- Monitoring from space, aircraft, and surface

THEME 3 mitigation options, scenarios, reduction strategies, policy and implementation
- Industry
- Government
- Public private partnerships
- Agriculture

THEME 1 SOURCES, SINKS AND INVENTORIES

Industrial processes, crop production and animal husbandry
Chairs: André van Amstel and Adrian Leip

Julio Mosquera presented information on N2O emissions from fertilized grassland and arable land in sandy soils. The highest N2O emissions were measured during fertilization events with cattle slurry and mineral fertilizers. The highest emissions were measured from narrow band injection of cattle slurry.

Daniel Weymann presented estimates of indirect agricultural N2O emissions from contaminated aquifers. The IPCC emission factor for indirect agricultural emissions from aquifers has been downscaled from 0.025 to 0.0075 in 2006 with a range of 0.0005 to 0.025. This was based on work by Weymann and others where they measured low emissions from aquifers. The improved emission factor is based on an estimate based on the initial NO3- present in the groundwater (Weymann et al, 2008 in Biogeosciences)

Adrian Leip presented direct N2O emissions from agriculture in Europe as calculated with the indicator database for European agriculture. Direct N2O emissions from agriculture have the largest uncertainties in the estimates for Europe. Most countries use default IPCC emission factors. The aim of this research is to reduce the uncertainty by developing a more detailed tier 3 approach to estimate N2O emissions.

Jan Peter Lesschen and Gerard Velthof presented information on N2O emission factors from soils. The main factors controlling N2O emissions are nitrate content, oxygen content, available carbon, temperature and pH. A study was conducted to assess the effect of different circumstances on the default emission factor of 1% of added N for grassland on a sandy soil fertilized with calcium ammonium nitrate. They found a calculated N2O emission factor ranging from 0 to 10%. A detailed table was developed for emission factors.

Hans Kros et al. presented information on the impact of mitigation options on nitrous oxide emissions caused by the agricultural sector in Europe. For the EU27 an overall N2O emission was found of 347 kton N2O-N for the year 2000. A reduction of 25% seemed to be feasible with the evaluated mitigation measures. The most effective measures are balanced fertilization -14%, and maximum manure application -7%. Mitigation is highly variable per country. A map was produced with results for Europe

Yunfan Wang et al. presented information on the effects on yield, soil carbon and greenhouse gas emission of field management in winter wheat in the North China Plain. The results were based on field experiments. Treatments were with Tm manure, Tri residue incorporation, Trm residue mulch, Tnt no tillage, and Trr residue removal. The yield and soil organic matter renewal was reduced with these treatments in this order. Conclusions were that farm yard manure will increase yield, soil carbon but also greenhouse gas emissions. More residue incorporation has benefits for soil carbon and yield and resulted in reduced greenhouse gas emission. No residue return, or just chemical fertilizer or no tillage is not enough to maintain soil carbon. N2O emission is 2.6 to 11.6% of added nitrogen, methane emission is negligible.

Sander van Zijderveld et al. presented information on methane mitigation in ruminants using feed additives in dairy cattle. Methane production, animal performance and milk production were unaffected when using garlic derivative, yucca powder and calcium fumarate. Caution is needed when methane reduction measured in the laboratory is translated to the real animals.

André Bannink et al. modelled effects of grass management on manure nitrogen and methaneemission in lactating cows. They found that grass management and grass quality have a profound impact on N excretion, manure composition, N emission from excreta and applied manure on the one hand and on methane emission from enteric fermentation on the other hand. However in opposite direction. High levels of N fertilization reduce methane emission whereas N excretion and subsequent N emission from soils increase. They used a process based model to assess methane emission from dairy cows. The current results imply that decreasing the intensity of grassland management in the Netherlands may increase direct on-farm equivalent CO2 greenhouse gas emissions.

Karin Groenestein et al. presented information on the effect of straw bedding in pig housing on emissions of greenhouse gases. The emissions of nitrous oxide and methane from straw littered systems in pig husbandry are very variable. The key factors greatly depend on litter management. The data indicate that where slurry based systems emit no nitrous oxide, emissions remain low when the bedding material is straw instead of wood shavings or sawdust. Considerable amounts of methane may be produced in deep litter systems but actual methane emission is limited because methane is oxidised in the top layer of the straw bedding.

Stefan Lechtenbohmer and Carmen Dienst presented scenario results of methane emissions from the future developments of the upstream gas industry in Russia. Natural gas makes an increasing contribution to the European energy supply. Due to its efficiency and low level of combustion emissions this reduces greenhouse gas emissions compared to the use of other fossil fuels. An increase is expected in the next decades of Russian gas imports for the German market. This could mean higher losses of upstream methane unless investments are stimulated in new technology particularly in Russia.

Emission inventories and high tier emission models
Chairs: Julio Mosquera and Tinus Pulles

Tinus Pulles presented information dealing with the question whether or not non-CO2 greenhouse gas emissions from industrial activities should be included in emissions trading. Analysis of data from either annual emission reports, emission trading or the European Pollution Emission Register (EPER) showed no inconsistencies for CO2 for combustion processes. For CH4, limited data was available from EPER, and inconsistencies were observed. For N2O, not many EPER reports were available, and several inconsistencies were found. For non-combustion processes, it may be not worthwhile including non-CO2 greenhouse gases in emission trading, because of the uncertainties in the data, the costs and because only a limited number of facilities could be included.

Gerard Velthof described the processes controlling the emission of N2O from soils. Since the number of factors affecting theses emissions is large, it is difficult to quantify N2O emissions from soils. However, denitrification seems to be the main process leading to N2O production in soils. N2O fluxes show a high spatial variability, both within and between fields. Insight in spatial variability is necessary in order to define a good measurement strategy (number, dimension and placement of flux chambers). Insight in factors controlling N2O fluxes is important in order to come to new mitigation options.

André Bannink presented a Tier 3 dynamic model used to estimate methane emissions in dairy cows for the national inventory report. The model is based (if possible) on *in vivo* measurements, and differs therefore from other mechanistic Tier 3 models. The major errors associated to the presented model were the feed intake, then dietary components and then chemical composition. The model does not represent details on rumen H2 balance, but can be used as research model with testing scenarios.

Anton Visschedijk showed data on the emission and spatial distribution of elemental and organic carbon for Europe in 2005. Organic carbon emissions were always higher compared to the emissions of elemental carbon, with the only exception of the transport sector. Small particles are much more relevant for climate, transport and health than coarse particles. Based on the available data, it seems that the concentration of elemental carbon might be underestimated by a factor of two.

Wim de Vries presented European wide predictions of nitrogen and greenhouse gas fluxes in response to changes in land cover and land management. These predictions were based on three different models working at different scales: 1) Initiator (The Netherlands); 2) Miterra (Europe); and 3) Image (World). Spatial aggregation had a limited effect on national and continental scale emission estimates, but a large effect on regional scale emissions.

Verification of emissions
Chairs: Christy van Beek and Guus Velders

Simon O'Doherty presented information on the growth of HFC-125. HFC-125 is being used for refrigeration as replacement of ozone depleting compounds. Its presence in the atmosphere started in about 1994 and currently shows a strong increase of 16% per year. The global 2007 emissions derived from these observations is 21 kton/yr and increasing. Due to the increasing concentration and large GWP(100 yr) of 3500, HFC-125 can contribute significantly to future climate forcing. Observations also show increases in concentrations of other compounds used to replace ozone depleting compounds. Observations of HFC-134a, HFC-152a and other HFCs are all increasing.

Jakub Bartizel presented new atmospheric observations of SF_5CF_3. SF_5CF_3 is an interesting compound due to its large GWP(100yr) of 18000. The sources of SF_5CF_3 are not well known, but might be associated with the production of halocarbons and SF_6. Its atmospheric concentrations has increased since the 1960s, but now seems to level of.

Sylvia Walter presented new information on hydrogen. Hydrogen (H_2) in the atmosphere is receiving more and more attention due to its possible future use as an

energy carrier. Using the ratio between atomic hydrogen and deuterium information can be obtained from the national and anthropogenic sources of H_2. A large source is from the oceans from an organism called trichodesmium. The results of a field campaign measuring H_2 on a ship from South America to Europe were reported.

Carolien Kroeze presented some information on aquatic emission of N2O. The aquatic emission of N_2O account for about 30-40% of the total global N_2O emissions, but regional differences are large and verification is largely lacking. Most N_2O budget studies neglect N_2O uptake. However, in fact this process is often occurring, especially in temperate, N-low environments. The sinks should be included and thereby the global N_2O budget could be largely closed.

Surinder Saggar presented a nice study from New Zealand. Different experimental methods (micrometeorogical and flux chamber) may yield different results. For a study in New-Zealand two experimental methods were compared with DNDC modeling. The model was best fitted to the flux chamber experiments. About 20 replicates were needed to cover spatial variability. More replicates did not decrease spatial variability, but did increase confidence of cumulative fluxes.

In forests about 7-11% of the N_2O emissions is caused by N deposition.

Louise Barton presented three years of continuous measurements of N2O in Australia. In the semi-arid region of Western Australia average N_2O emissions for cropped soils equaled 0.3 kg N/ha/y. There was little response to fertilizer application and therefore mitigation strategies may be found in the use of nitrification inhibitors. However, the fluxes were very low and are used to set emission factors for arable agriculture in semi-arid regions.

THEME II MONITORING AND MODELLING

Special session on methane

With near to 30 presentations and another 10 posters methane appeared to be the hottest topic of the 5th NCGG conference. The present interest in methane was fuelled by new uncertainties in the global methane budget which became apparent when its concentration started to rise at a faster rate than expected in recent years.

Keith Lassey pointed out that, while apparently total global emissions per year exceed the total removal by sinks, such as soils, leakage to the stratosphere and, most importantly, destruction by the hydroxyl radical in the troposphere, a closing explanation of the reasons for the unbalance is difficult. He compared the $^{12}CH_4$ concentrations with the ^{13}C isotope, in order to discriminate between fossil and biogenic sources. The time-resolved results, however, were not consistent with trends in atmospheric levels over a number of years and did not resolve uncertainties in existing emission inventories.

Jos Olivier reported on the EDGAR global database, version 4.0, which now contains 24 greenhouse gases. His data indicated increases in global emissions for CO_2 and N_2O, in particular since the year 2000. For methane an exceptional increase by 11% since 2006 was noted; it followed upon a documented reduction of emissions from landfills, coal mining and wastewater treatment of 13 Tg CH_4 (~3% of global

emissions in 2005). F-gases showed an increase throughout as well, exceptions are the PFCs and SF_6.

Source strengths
With respect to source strengths *Vigano* provided data on methane emissions from vegetation triggered by exposure to UV-radiation and estimated a contribution in the order of 3-4 % of total emissions. *Schrier* did not find much difference between soil emissions form either natural or agricultural soils in the Netherlands. *Van der Laan* deduced from flux measurements, calibrated by ^{222}Radon fluxes, that methane (and nitrous oxide) emissions might be lower by 20% than earlier estimates in the present Dutch emission inventory. *Weber* and by *Neef* reported results from inverse modelling studies to assess source strengths. *Christensen* reported on the increasing permafrost thaw in Sweden with proportional increase in emissions (~20%/year). In the fall refreezing of the wetland causes an emission event; it is assumed that freezing causes a sqeezing-out of the methane.

Possible explanations
Could monitoring studies throw light on the causes of the methane increase? As pointed out by *Bousquet* that satellite data have to be complimented by ground-based monitoring and air-borne campaigns.
Krol reported on the role of tropical biomass burning in the increase of methane emissions. On the basis of the results of his team he considered changes in emissions of biomass burning or wetlands unlikely and proposed the OH-variability in the atmosphere as a possible explanation. *Lassey* proposed that a reduction in the strength of the chlorine sink in the atmosphere could contribute to the increase of methane concentrations. *Bousquet*, reminding that methane emissions in Europe had shown a downward trend, held it for likely that tropical wetlands may be held responsible for increased emissions. This view was substantiated by results from the Amazon BARCA project on the differences in the methane/CO ratio in the dry and the wet season, as reported on by *Beck*.

THEME III MITIGATION AND SCENARIOS

Industry

PFC emissions reduction by the semiconductor industry

Francesca Illuzzi of Numonyx and Harry Thewissen of NXP Semiconductors made a presentation on the way of working of and activities by the semiconductor industry to reduce global warming by voluntarily reducing its PFC gases emissions. The agreed 10% reduction goal in 2010 will be reached and even exceeded. If the growth of the industry is taken into account, this corresponds with an absolute emission reduction of about 90%. Key to the success has been the intensive collaboration within the industry and the strong involvement of equipment and gas suppliers. The semiconductor industry considers it already as a masterpiece to maintain future absolute PFC emissions at the 2010 levels.

Low global warming fluorocarbons

Ian Shankland of Honeywell Intl. presented promising results on the application of two new fluorocarbon compounds with low GWP as air conditioning refrigerants.

Kirsten Taddonio of the US Environmental Protection Agency discussed the same issue. She showed, that by switching to new refrigerants with more benign properties NCGG emissions from mobile air conditioning could be reduced in a cost-effective way.

Wim Porte of Eaton Electronic BV made a presentation on the use of SF6 in electrical networks. His conclusion is that SF6 is no longer needed in medium voltage applications, as there exist alternatives.

Thor Endre of ABB AS showed another angle of incidence to reduce SF6 emissions from electrical networks. His message is that by proper handling procedures and by improved system designs the emission of SF6 can be largely avoided.

Joey Lu of ITRI (Taiwan) made an interesting presentation on the verification process of the efforts by the Taiwanese electronic industry to achieving reduction of fluorocarbons use and emission.

Government and mitigation

Chair: Carolien Kroeze. In session 3.2 (Government), three papers were presented on Wednesday morning 1 July.

The first paper, presented by Elaine Matthews (NASA, USA) addressed the question whether reductions in methane and black carbon can provide swift climate responses (Baum et al., 2009). The presentation first focused on the relatively large differences that exist between emission databases for CH_4, indicating that the uncertainties in the global methane budget are still considerable. Next, new future baseline and mitigation emissions of methane and black carbon were presented. Baseline and mitigation projections of black carbon for 2000 and 2030 formed the basis for estimates of radiative forcing by black carbon and co-emitted SO_2 and other carbonaceous-aerosol emissions (OC). The results indicate that 2030 radiative forcing of black carbon alone (0.32-0.49 W/m^2) is substantially offset by co-emitted SO_2 and OC which contribute a large negative forcing (-3.61 to 3.94 W/m^2). Moreover, relatively small changes in BC emissions can be associated with unexpectedly large offsets from co-emitted species. The most important conclusions from this paper are (1) the available projections for future trends in greenhouse gas emissions lack transparency, (2) *plausible* scenarios are needed, (3) reducing emissions of BC and methane has multiple advantages, and (4) co-emitted substances may offset the direct radiative forcing.

The second paper was presented by Wilfried Winiwarter (IIASA, Austria), and focused on emission mitigation potentials and costs for non-CO_2 greenhouse gases in Annex-I countries according to the GAINS model (Winiwarter et al., 2009). IIASA's GAINS model is an effective tool to evaluate air pollution and greenhouse gas (GHG) emissions, and mitigation measures. The model includes projections for future trends in emissions of pollutants contributing to acidification, eutrophication, ground level

ozone and global warming. It also includes abatement options, and their costs at the country level. In his presentation, Winniwarter first compared national emissions of non-CO2 greenhouse gases from GAINS with the National Communications of European countries. Next, GAINS model results were presented. The GAINS model was used to assess mitigation potentials for 2020 for all countries covered in Annex-I of the Kyoto protocol. Mitigation measures for methane, nitrous oxide and fluorinated gases were presented as well as their national costs. An important conclusion was that for non-CO_2 gases not many options exist at negative costs. This is in contrast with CO_2, for which a number of options exist at negative costs (~25% of the overall reduction potential). Non-CO_2 gases, however, provide considerable potential in the very low cost range (less than 10 €/t CO_2-eq), also as they are affected by options to abate CO_2 as well. The GAINS results indicate that at this stage of the very cheap options, non-CO_2 gases kick in at 36% of the reductions up to that cost. This share is then decreasing for the higher cost range, to about 26% for a carbon price of 100 €/t CO_2-eq.

The third paper dealt with the potential to reduce emissions of fluorinated greenhouse gases, and the associated costs (Hanaoka et al., 2009). This paper was presented by Tatsuya Hanaoka (National Institute for Environmental Studies, Ibaraki, Japan). Mitigation potentials were estimated for fluorinated compounds in 23 global regions and marginal abatement costs (MAC) were evaluated for the year 2020. The study included hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6). Mitigation potentials in the 23 global regions were estimated based on a bottom-up approach with a detailed technology selection framework. Emissions to the atmosphere were estimated while taking into account the time delays between consumption and emission for each category and each end-use. The mitigation potentials for HFCs, PFCs and SF6 were estimated at about 300 $MtCO_2$ eq on a global scale under 100 US$/tCO2 marginal abatement cost in 2020. The results indicate that there are considerable mitigation potentials in the U.S., China, EU15, Japan and Russia, accounting for approximately 80% of the total reduction potential in the world. Recovering and decomposing refrigerants from refrigeration and air conditioner was identified as an important reduction option.

Government
Chair: Michael Rumberg

Marlene Sieck from the German Federal Environmental Agency outlined the success story of legal requirements for landfill sites in Germany. Since inception of the policy methane emissions have been reduced from 1.7 Mio. tonnes in 1990 to 0.4 Mio tonnes in 2007. Key driver for the rapid change was the introduction of new legislation.
Erik ter Avest from Senter Novem in the Netherlands presented a tool kit for the implementation of behavioral changes also in emissions mitigation related projects through various instruments such as legislation, incentives, education or personal advise. As applications in the Netherlands and China have proven the tool helps to find out which instruments will have the most impact to result in changed behavior. Furthermore positive examples of public-private partnerships in non CO2 GHG projects were shown.
Marcus Sarofim from EPA in the US introduced the concept of a metrics for black carbon. As black carbon is mentioned in the upcoming US legislation on climate change issues (Waxman-Markey-Bill) a metrics would allow a incorporation into

CO2-based emissions trading systems. Nevertheless a inclusion of black carbon in emission trading systems is currently not recommended due to too high uncertainties and the bigger differences in substances lifetime.
David Godwin from EPA in the US demonstrated reduction opportunities for consumption of HFCs. As per his studies the implementation of all available measures would allow to almost meet the reduction obligation foreseen in the current legislation.
Arja Even from Senter Novem in the Netherlands introduced the changed approach in governmental funding. Previously the funding was distributed more broadly whereas recently the funding focuses on major emissions sources as per the impact to the overall carbon balance.

Public Private Partnership
Chair: Erik ter Avest

Deborah Ottinger presented fluorinated gas emission reductions – a decade of progress through voluntary partnerships with industry.
The American Environmental Protection Agency started public private partnerships to reduce fluorinated gas emissions of PFC, SF6 and HFC23. The aim is to boost technology to reduce emissions cost-effectively in three steps: Profile emissions, Information sharing and Results. The voluntary strategy is geared towards pollution prevention, shared research and challenging technical aims. Quality Assurance & Quality Control delivers validated data and credible results.
Lessons learned after more than 10 years of voluntary measures: Real reductions have been achieved without regulations. A clear and shared focus results in motivation. Leaders of industry should cooperate to make large steps ahead. Results revolve around good alternatives for polluting chemicals, more efficient production processes, best practices, fast replacement of obsolete machines.

The focus for voluntary partnerships in 2009 of the US is in ‘tracking and reporting’ to improve data and monitoring of reductions. Continuation of the search for new cheap mitigation Technologies. Stimulating broad strategies for complete branches and information sharing.

Erik ter Avest presented “A good Public Private Partnership works”
In the Netherlands and Europe Public Private Partnerships are part of the policy mix to reduce emissions of fluorinated gases. An example is the semi-conductor industry. Other PPP’s have been initiated in the Netherlands program for the other greenhouse gases which has seen large reductions over the period 1999 to 2010. The reduction program had three phases: Inventory of emissions, mitigation options and research and development, implementation of options. In working groups the options were discussed with industry and aims and targets were negotiated. It proved important to be open in communication. Results sometimes were forced with credible threats with sanctions. It proved to be more cost effective than law and regulations if industry was involved and responsible for good options and measures. In cooperation with China it proved effective to promise industry regular provision of electricity in return for cooperation.

Deborah Ottinger presented Progress in PFC Emission Reductions from the Aluminum Sector in China through the Asia Pacific Partnership (APP) for Clean

Development and Climate.
The US EPA developed cooperation with the Asian market through an Asian Pacific Partnership (APP). This APP aims to reduce PFC emissions from the aluminum industry in Asia. China with more than 80 smelters is the largest producer of aluminum in Asia. Improvements in the production process will help to reduce a large part of the PFC emissions from aluminum. The APP brings together experts and government and knowledge of best practices from the US and Europe.

Agriculture- part 1: cost effective mitigation options
Chair: Cecile de Klein. Two talks in the agricultural session dealt with modelling of GHG emissions and assessing the most cost-effective mitigation options.

The first talk by Robert Beach described an approach using marginal abatement costs curves to assess the most cost-effective mitigation option. This approach used the DNDC and Daycent models and literature information on mitigation options for livestock to assess GHG emissions and mitigation potentials for a rice case study in China. The choice of the MAC curve methodology (optimistic, conservative and incremental) strongly affected the results, and showed that incremental responses are very important to consider. The approach worked well but a question was raised about the origin of the input data and of the reduction potential values of the mitigation options. These were generally taken from the literature and there is some uncertainty around these. The next steps in the process will be to conduct a sensitivity analysis and extend the range of options.

The second talk by Tokomo Hasegawa described a linear modelling approach to assess global N_2O and CH_4 emissions and reduction potentials of 20 technologies for which reduction information was available. This approach also used a selection of models (both global trade and biophysical) to optimise the reduction potentials at least cost. The study suggested that GHGs will increase 14 times by 2030, that India, China and USA are the most effective regions for mitigation, and that most the effective technology and source of reducing GHGs were daily spread of manure and rice-paddy emissions. Again the approach was relatively simple and worked well but a question was raised about the origin of the input data and of the reduction potential values of the mitigation options.
Both studies highlighted the challenges of spatial and temporal variability, multiple GHGs and their interactions, availability of regional specific data and the assessment of the reductions achieved by a mitigation technology.

Agriculture- part 2 Implementation
Chair: Wilfried Winiwarter

The second part of the session focussed on the implementation and the information transfer of scientific/technological knowledge for practical use. Greenhouse gas emissions in agriculture, which play the major role for NCGG's, have to be tackled by many individuals, the farmers. Informing and convincing this large number of individuals is a specific challenge. As Maarten Kool from the Dutch Ministry of Environment explained, the Dutch plan to achieve climate goals attempts to create and identify win-win situations which allow reduction of greenhouse gas emissions (a target of 30% reduction between 1990 and 2020 has been set also for agriculture) combined with economic benefits. The Dutch government invests into research which

will allow such improvement. The hands-on work with individual farmers, again in the Netherlands, was described by Ida Smit of SenterNovem, a Dutch government agency. In her experience, the farmers themselves know the operation of their farm and the most suitable reduction measures best, so they need to be involved in the choice. But first of all they need to become aware of their contribution to the greenhouse gas emission. This works better in a more interactive way, e.g. interactive games and discussions, than with brochures and research reports. Convincing her own ministry is still the task of Martina Havlikova from the Czech ministry of Environment. Her presentation covered modelling individual and overall environmental impacts of the dairy production sector for nine Czech study regions. The model finds cost-optimal solutions for tackling greenhouse gas emissions. This result is not reflected in the current national policy.

Agriculture- part 3 Results of implementation
Chair: Ida Smit

In the last part of the session about Agriculture three studies were presented in which estimations as well as field experiments had been practiced. Cecile de Klein presented the results of a study in which the greenhouse gas emission of different farming systems in New Zealand has been estimated and compared with each other. The emissions were estimated with more or less detailed calculation rules used for the inventory reports (TIER 1, 2 and 3). The different charging systems had been compared. The ratio of the emissions of the different farming systems didn't depend very much on the accuracy of het calculation method. At the current pricing level the charging systems have no influence on the farming systems which differ in cow numbers, use of N-fertilisers, amount of imported feed and genetic merit.

In China the meat consumption increases due to the population growth. Also the agricultural activities grows, and simultaneous the agricultural N2O emissions. Wilfrief Winiwater showed the hot spots of the N2O emissions, gathered from regional maps of fertilizer consumption. The expectation is that the N2O emission will increase by 30% in 2030 as a result of the increasing livestock amount and the N-fertilizer use. However, the uncertainty of estimations of N2O emissions are high. Promising mitigation measures are nitrification inhibitors and efficient application of fertilisers. Nitrogen inhibitors can reduce agricultural N2O emissions by 4 to 16 percent.

Tassanee Jiaphasu-anun, a Phd-student of the University in Bangkok, explained the field experiments in rice fields in Thailand. Rice straw burning will be prohibited because of the abatement of air pollution. The alternative, incorporated rice straw, increases the methane emission. Tassanee compared the yield of the fields with rice straw burning and rice straw incorporated, and the effect of drainage on the yield and the methane emission. The field experiments showed that the application of water drainage during flowering period can decrease the methane emission.

General conclusion

The conference was very successful in bringing together science, technology and policy on non-CO2 greenhouse gases. Many new scientific developments were presented. The most important of which is the increasing methane concentration in the

air since 2007 despite widespread reductions in methane emissions as officially reported by industrialised countries. No definite conclusion could be reached about the reasons for the increased methane concentrations which are measured in the northern but also in the southern hemisphere. It was advocated to reduce methane and black carbon at the same time for the best result in terms of reduced climate forcing.

Nitrous oxide emissions will grow with increasing food production for a growing world population especially in China and India. Emissions will only be reduced through precision agriculture with reduced fertilizer applications.

A new activity during the conference was the test of ideas through voting. Most of the participants were scientists working full time on non-CO2 greenhouse gases at the interface with policy and technology.

In industrial gases like PFC's, SF6 and HFC's. Lessons were learned after more than 10 years of voluntary measures. Real reductions have been achieved without regulations. A clear and shared focus results in motivation. Leaders of industry should cooperate to make large steps ahead. Results revolve around good alternatives for polluting chemicals, more efficient production processes, best practices, and fast replacement of obsolete machines.

The conference participants have discussed the information needed to speed up the process of technical emission reductions in all countries in the world. Examples were presented on new public private partnerships to reduce emissions for example in Europe, China and in the USA. The general conclusion was that more reductions can be achieved through these public private partnerships through active participation in other countries. Most participants had the feeling that not enough attention was paid to non-CO2 greenhouse gas reductions in their countries. Legal instruments were seen as the most needed to speed up emission reductions although most participants felt that a combination of instruments including communication would have the best effect.