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Integrated assessment and co-control approaches

Bjarne Sivertsen
NILU, Norwegian Institute for Air Research

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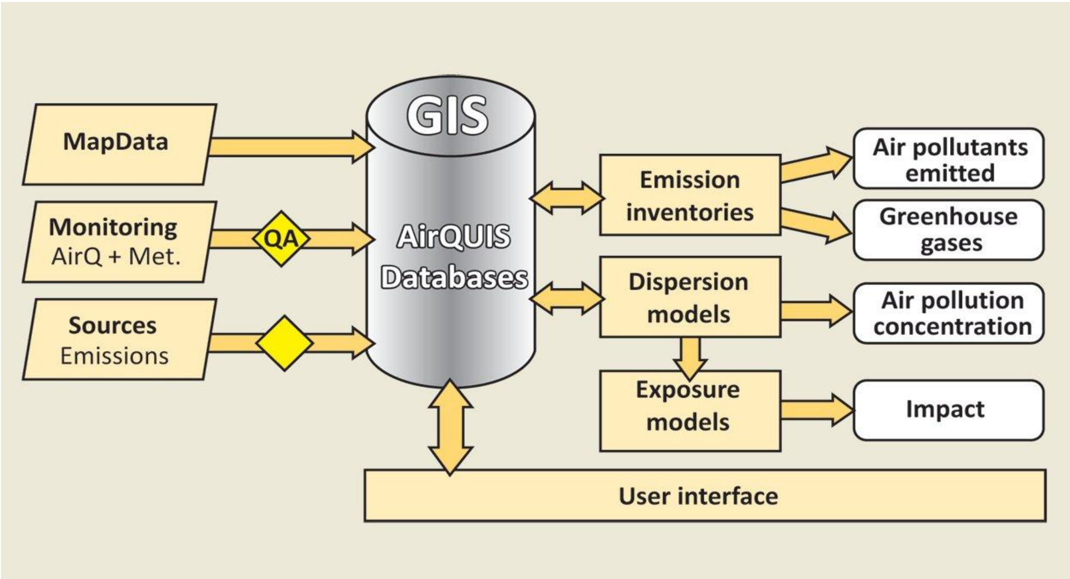

Norsk institutt for luftforskning
Norwegian Institute for Air Research

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Integrated assessment and co-control approaches

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Abstract
Today's air quality management requires integrated and coordinated measures where urban air quality planning includes also greenhouse gas (GHG) emissions and climate change issues. Several studies evaluating different strategies were recently performed in Norway, looking at different geographic areas in and outside Norway.

In both developing and industrialized countries, abatement of air pollution and mitigation of climate change have generally been treated separately. The tools that have been made available for investigating scenarios for reducing local impacts and health effect improvements can also be used in order to investigate cost effective actions aimed at reducing greenhouse gas emissions. The approaches presented are based on the air quality management and planning tool producing bottom-up emission inventories. The data available in these studies enable estimated of GHG emissions and evaluation of co-control strategies. These approaches would lead to a co-control and co-benefit as it will both improve the health of people and give climate benefits at best possible costs.

Approaches prepared for co-benefit studies in Norway as well as plans for co-control projects in other countries. These approaches also have lead to specific developments and focus on issues previously not included in traditional air pollution abatement studies. Examples are given for a scenario analyses undertaken in Oslo based on 2009 and 2015 emissions. Emissions of pollutants as well as concentration and exposure estimates have been presented. Also the impact on GHG emissions is part of the analyses.

The integrated impact of carbon capture technologies being developed in Norway is also discussed as part of mitigation measures that may create contradicting impacts between local and global issues.

1 Introduction

The need for an integrated approach, which treats air pollution and climate issues simultaneously, was demonstrated at several recent occasions (Gap forum, 2008) (EFCA, 2009). The institutional separation of the two domains may not favour a satisfactory execution of the total issue. This triggered an analysis of EU legislation on climate change and air pollution which was discussed in 2008 in a European Symposium in Strasbourg (SCARP, 2009).

The focus has thus shifted from local air pollution and its threat to health and environment, toward global threats due to greenhouse gas (GHG) emissions and their impact on climate. In both developing and industrialized countries, abatement of air pollution and mitigation of climate change have generally been treated separately. There are, however, large benefits in considering the control options together; such approaches would mostly lead to increased health and/or climate benefits and decreased costs.

As global warming has recently taken most of the focus in the political decision processes, local and regional challenges seem to have been set aside. Today's air quality management requires integrated and coordinated measures where urban air quality planning includes also greenhouse gas (GHG) emissions and climate change issues. Several studies evaluating different strategies were recently performed in Norway, looking at different geographic areas in and outside Norway.

NILU has recommended decision makers to take a balanced view, as it is possible to reduce both GHG emission and local pollution simultaneously. International experience shows that climate change mitigation can result in a simultaneous reduction in air pollution. IPCC states in its fourth assessment report that "integrating air pollution abatement and climate change mitigation policies offers potentially large cost reductions compared to treating those policies in isolation" (IPCC, 2007).

2 Possible co-benefits

The IPCC recommends co-benefit thinking in the climate change mitigation. To support this argument, a number of technologies and measures in the energy supply, transport, building and industry sector have been identified to also help abate urban air pollution.

Focusing on co-benefit actions is now and will in the future, be an important part of NILU's research both in the local and regional air quality management planning. It is necessary also in the study of climate change, including the study of mitigation steps and their effects.

A stringent global climate policy will lead to considerable improvements in local air quality and consequently improves health. Measures to reduce emissions of greenhouse gases to 50% of 2005 levels, by 2050, can reduce the number of premature deaths from the chronic exposure to air pollution by 20 to 40%. (Bollen et.al 2009).

Climate policy will already generate air quality improvements in the OECD countries in the mid-term; whereas in developing countries these benefits will only in the longer run show to be significant (OECD, 2008).

The integrated long-term cost-benefit approach balances the means to lower simultaneously the adverse impacts of climate change and air pollution and shows significant climate benefits after 2050. In summary, these simulations and results from the literature review suggest that for countries giving priority to GHG mitigation, the local air pollution co-benefits provide an additional incentive by off-setting a proportion of the GHG mitigation costs. These co-benefits could be larger than currently estimated since most estimates omit the possible co-effects of GHG mitigation on indoor air pollution, which is expected to be large in countries such as India and China as stated by IPCC in 2007 (Parry et.al 2007).

3 Climate policy and local impacts

The background for measures employed in Norway is to be found in several commitments. In addition to the need to comply with air quality directives, Norway undertakes to reduce global greenhouse gas emissions by the equivalent of 30% of its own 1990 emissions by 2020, and intends to cut the global emissions equivalent to 100% of its own emissions within 2030. In other countries, most notably in China, authorities are also increasingly looking to measures that simultaneously improve local air quality and reduce GHG emissions.

Measures to achieve these goals include moving from fossil based energy to more use of bio fuels. This however may change the environmental challenges. While the GHG emissions will be reduced, emissions of particulate matter, nitrogen oxides and poly aromatic hydrocarbons may increase and give rise to more local air pollution as well as to a more harmful pollution composition, and increase the exposure of human populations. Combination of changes in local air pollution impacts and GHG emissions may also lead to increasingly harmful effects on our built cultural heritage.

3.1 GHG reductions may lead to local side effects

To focus solely on GHG emissions may cause unwanted side effects. One of the first steps taken by the Norwegian government to cut back domestic CO2 emissions is likely to fall into this category: The decision of reducing taxes on the purchase of diesel cars as they emit less CO2 than fuel cars proved to be a success. In one year, the market share of diesel cars increased from 48.3% in 2006 to substantially 74.3% in 2007. However, the downside of the “success” may be a substantial increase in local air pollution, with a subsequent damaging effect on human health. Recent research has shown that the pollution will continue even with the introduction of filter fittings, as the filter itself contributes to an increase in the damaging NO2 emissions.

Diesel engines emit, depending on their condition, about 20 percent less of the greenhouse gas carbon dioxide (CO_2) per kilometre than the same car type with gasoline engines. However, besides CO_2, the exhaust contains a number of other components such as nitrogen oxide (NOx), carbon monoxide (CO), and particles (Strømme et al 2008). Because of the different compositions of emissions and many different climate effects on different time-scales, comparing diesel and gasoline is not straight forward. In addition, the effects on air quality and health have to be taken into consideration.

4 Carbon capture and integrated assessment

Being an energy rich nation with a strong focus on challenges of climate change, Norway aims to make carbon capture and storage (CCS) a reality. Today three major CCS projects are progressing: The Norwegian Government Gassnova and Statoil are collaborating on a test facility as well as developing a full scale CO_2 capture facility at a gas-fired power plant. Furthermore, Shell and Statoil have signed an agreement to work towards developing the world's largest project using carbon dioxide for enhanced oil recovery offshore.

Studies of the co-benefit of different policies, most notably in the area of air pollution and climate change abatement, have required further need for research and developments. These include development and application of integrated assessment taking into account various geographic scales, improved exposure assessment for human population and establishment of exposure-response relationships, as well as further studies to increase our knowledge on local and regional aerosol formation and its influence on climate forcing and weather patterns.

4.1 CO_2 capture with amines

The reduction of CO_2 in this case will have to be evaluated against other local and regional impacts in an integrated manner. A screening study was started in order to study possible effects on human health and nature. The critical loads and limit values were evaluated based on model estimates (Berglen et.al 2010)..

Even if the amine technology is considered the most mature technology for post-combustion reduction of CO_2 there is still uncertainties connected to the integrated impact of this technology. It may lead to releases of amines into the atmosphere. The following amine oxidation in the air is not well studied to date, and the effects are still uncertain.

Compounds derived from amines are toxic to vegetation, aquatic organisms and to human health if exposed to high concentrations in air. The first evaluations, however, indicated that nitrogen loads from amines from CO_2 capture plants alone are not critical to endangered ecosystems (Knudsen et.al 2009).

The results of the preliminary analyses have demonstrated that CCS technology development must be a holistic approach. CCS must in addition to being climate friendly also be environmental friendly. The exact emissions are not known, neither in quantity nor composition. The choice of amine is not irrelevant for the environmental impact. The mother amines probably represent the highest emission rates, but may not be the largest problem concerning the local and regional effects.

5 Integrated studies and co-benefits

NILU has been performing urban air quality management and planning projects worldwide since the 1970s. During the last few years greenhouse gas emissions and climate change issues were also included in several of the impact evaluations (Larssen, 2007) (Sivertsen and Dudek, 2007).

One of the main issues is to what extent air pollution mitigation approaches will also reduce the GHG emissions or whether GHG mitigation costs would be partially covered by the co-benefits in terms of reduced local air pollution. The bottom-up emission inventories applied in local air pollution mitigation and air pollution improvement studies enable GHG emissions to be specified for individual sources or groups of sources. This will in turn enable GHG emission strategies to be specified enough to enable the costs of these actions to be estimated (Aunan et.al 2004). The approach will thus lead to a better understanding of the most cost effective actions both for reducing local impacts and reducing GHG emissions (Sivertsen, 2008).

5.1 The NILU planning tool

The AirQUIS planning tool has been developed by NILU to handle a number of air pollution tasks and challenges. It is based on a GIS based database including monitoring data, emission inventory tools and models. The main objective applying this planning tool has been to enable direct data and information transfer to perform user friendly emission data collections and to enable impact assessment using dispersion and exposure models (AirQUIS, 2007).

The system combines all these issues in one package. The module for emission inventorying enables to connect fuel consumption, energy use and industrial processes with emission rates. The system can thus estimate classical air pollutants as well as greenhouse gas emissions.

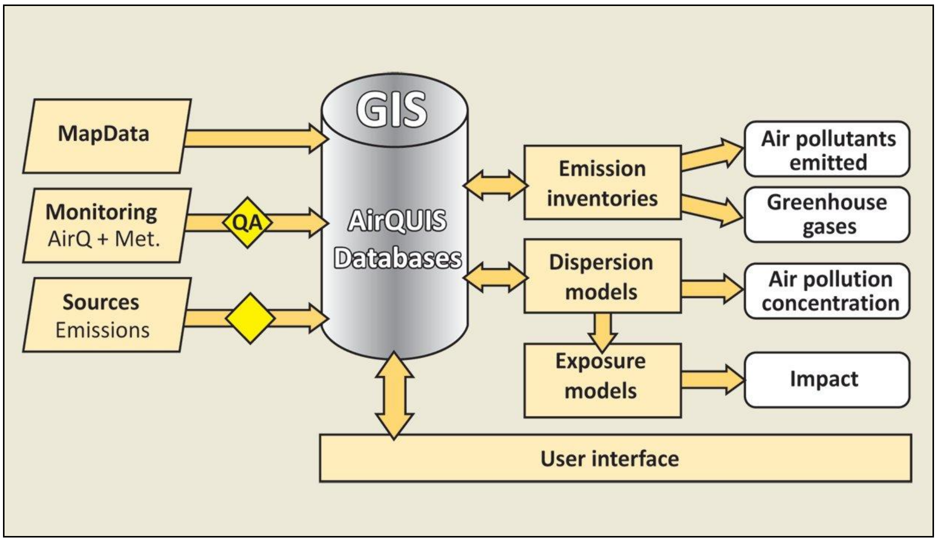

Figure 1: The NILU developed air quality planning tool; AirQUIS used in co-control studies.

The planning tool makes it possible for the user not only to present and evaluate the present situation, but also to perform impact assessment based on planned actions and scenarios. The system gives information both concerning local impacts and health effects and when GHG emissions are to be evaluated. The GIS platform, on which the system is operated, provides easy access to the data and gives a perfect and easily understandable data presentation tool.

5.2 Scenarios Oslo

Studies have been performed in Oslo in order to evaluate the exposure to people for alternative scenarios identified in order to reduce the air pollution impacts. The most important source to air pollutants in Oslo is road traffic. This is also an important source for greenhouse gas emissions. The transport sector represented the largest increase in greenhouse gas emissions, both nationally and internationally. More cars on the road leading more congestion and poor accessibility, and hence more emissions per car per km run. Emissions are greater for heavier than lighter vehicles, especially when driving slowly.

In 2008 the air pollution authorities were commissioned by the Ministry of Environment to create an action plan for local air quality. The plan was to propose measures that were necessary to achieve the national goals. A first draft was prepared in 2008 (Strømme et.al 2008).

The basis for this work was that the measurements at several monitoring stations showed exceeding the limits for PM10. Exhaust emissions from car, re-suspended dust from the streets as well as wood burning were the main sources of PM10, while for the road traffic was the main source for NO2.

Based on a complete emission inventory for Oslo, models were applied to estimate emissions of pollutants as well as emissions of CO2. The model shows that private households (including heating with wood and fossil fuels) accounts for around 50% of emissions of particulate matter PM10. Road traffic is responsible for 20% of the total PM10 emissions and about 55% of the NOx emissions in Oslo.

Exposure estimates have been performed for the years 2009 and 2015. Results of estimates for total number of people in Oslo exposed for concentrations exceeding the Norwegian regulatory requirements are shown in Table 1 providing that actions already decided are implemented.

Table 1: The total exposure, estimated as the number of people in Oslo living in areas where the hourly and annual average concentrations of PM10 and NO2 are exceeded.

Pollutant	All sources year	Total exposure (> hourly aver.)	Total exposure (> annual aver.)
PM10	2009	1 200	< 250
	2015	4 200	< 700
NO2	2009	9 600	50 000
	2015	2 400	19 000

For PM10 the model estimates show that the number of residents in Oslo exposed to levels exceeding regulatory requirements will increase by 60 - 70% up to 2015. Growth in traffic is the main reason for this increase. For NO2 the model estimates a reduction in the number of residents exposed to values above regulatory requirements.

The bottom-up emission inventory developed for air pollutants and aimed at evaluating the impact of pollution reductions on the local scale, was further applied to estimate the CO2 emissions in Oslo. CO2 from traffic is shown along the road system in Figure 2.

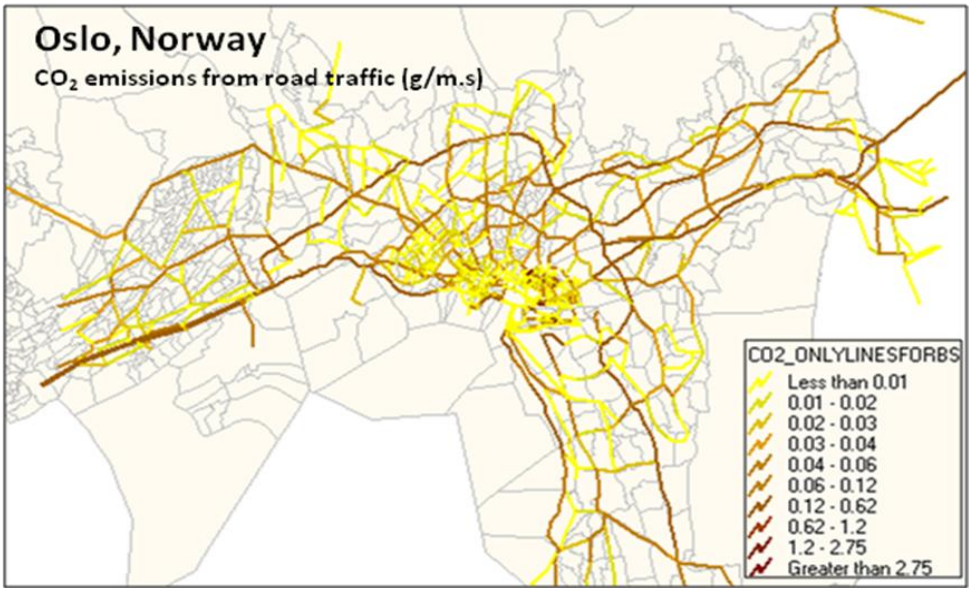

Figure 2: CO2 emissions along the road system in Oslo given as g/m.s.

These estimates have been used to integrate the emissions as shown and displayed on Google map for Oslo in Figure 3. As seen from Figure 3 there may be an area of maximum CO2 emission over Oslo which is up to 15 % of the background CO2 concentrations.

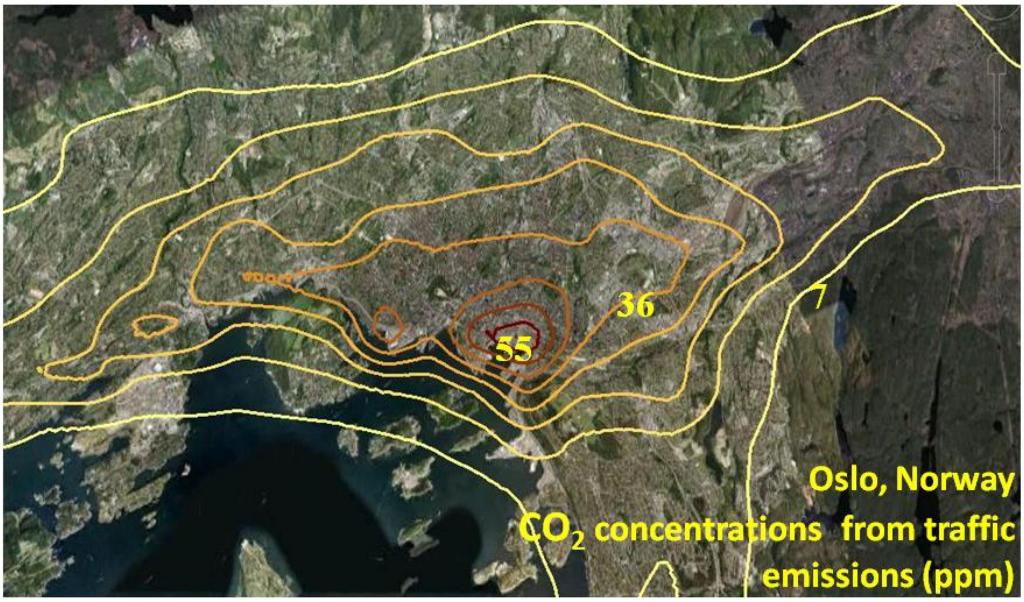

Figure 3: The distribution of the annual CO2 emissions from traffic sources in Oslo.

Several actions were included in the evaluation of an optimal abatement strategy for Oslo (Dalen and Amundsen, 2010). The possible actions and measures may be divided into 5 classes such as:

1. **Measures that reduce the number of vehicle kilometres:**
   Concentrated development of public transport hub
   Home office, video conferencing, etc.
2. **Measures that facilitate alternatives to car transport:**
   Public transport - better surface coverage, higher frequency, lower fares
   Better arrangements for pedestrians and cyclists - walking and cycling routes
   Park and ride
3. **Measures to restrict car transport on selected routes / time periods**
   Travellers Payment (time-differentiated road pricing)
   Low emission zones
   Parking restrictions
   Parking Fees
   Car-free zones
   Fuel Tax
   Costs of workplace parking moved to the user
   Maximum speed of the road network is set at 60 km / h
4. **Cleaner wood burning and**
5. **Harbour emissions**

For all these action estimates were performed in order to evaluate the local impact. Considerations were also discussed concerning the potential CO2 emission reductions based on the baseline emission estimate for CO2 emissions in Oslo as shown in Figure 3.

A summary of the final evaluation is presented in Table 2 below.

Table 2: The results of various actions planned in order to reduce the the impact of the emissions NO2, PM10 and CO2 in Oslo.

	Actions	NO_2	PM_{10}	CO_2	Comments
Traffic actions	Prices, parking, public transport, mobility	++	++	++	Reduce car-km driven in Oslo
	Mobility planning	+	+	+	Long term policies
Vehicles	Non studded tires	0	++	0	Dust reductions, no CO2 effects
	Low emission zones	++	++	++	Immediate effects
	Eco driving	+	+	+	Long term effects
	Ban idling	+	+	+	Effect on CO emissions.
	Electric cars public transp	+	+	+	Long term
Roads	Speed limit reductions	0	++	0	Immediate effects.
	Road cleaning	0	++	0	Immediate effects.
	Reduce tunnel emissions	+	++	0	Clean road tunnel emisisons
Wood burning	Cleaner stoves	0	++	+	Long term effects.
Harbour emissions	Reduce ship emissions, change fuels	++	+	++	Immediate effects, also SO2 reduced.

There are considerable co-benefits in implementing traffic actions in Oslo, which will reduce the number of kilometres driven. Also the introduction of low emission zones and measures for reducing ship emissions in the harbour of Oslo will give effects both on the local scale and on climate change issues.

6 General comments, integrated impacts

6.1 Largest integrated impacts in polluted areas

GHG abatement measures, such as changes in technologies to produce and consume energy, can also improve air quality by reducing emissions of pollutants including nitrogen oxides, sulphur dioxide, particulate matter and mercury. This can lead to substantial public health benefits. Even though the air quality co-benefits of climate change actions are well established, climate change policies do not typically account for them. Instead, the focus is on minimising the cost of climate change actions.

Incremental health benefits are larger when the starting levels of air pollution are high. Therefore as pollution emission reductions become more stringent, air quality co-benefits become less significant. The greatest air quality co-benefits were found in developing countries with high levels of air pollution. Even small reductions there are likely to have large health benefits. This implies that the most important time to include air quality co-benefits in long-term climate change strategies is at the beginning, particularly for developing countries without major air quality initiatives.

6.2 General reduced fuel consumption will give co-benefit

Measures that reduce the overall consumption of fuel, and thus total emissions of CO2 will benefit the global climate. Measures that provide a reduction of total traffic work in the city are examples of measures that both reduce emissions of greenhouse gases and will have a beneficial effect on local air quality.
Measures that lead to larger portion of diesel-powered cars will also be beneficial for the global climate, because fuel consumption is lower in diesel engines than in petrol engines of

the similar size. With the new particulate filters, the emissions of particulates will be almost the same for diesel and gasoline-powered cars. However, the emissions of NO2 will be higher from a diesel engine, thus creating a contradiction between local and global impact of such mitigation measures.

6.3 Large uncertainties

There are still large uncertainties in valuing the costs and benefits (including air quality benefits) of climate change mitigation. Improved evaluation techniques for both climate and air quality benefits in climate policy are needed; this is becoming an important area of research. Air quality co-benefits may not be considered important driving forces for strong climate policies unless their value can be reliably estimated.

Aknowledgement

The author will thank some of the NILU colleagues for valuable input to this paper. Karl Idar Gjerstad who was responsible for the scenario analyses in Oslo, Vo Thanh Dam who produced some of the figures for this paper and Svein Knudsen as responsible for CO2 capture project at NILU.

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With input from NILU colleagues:
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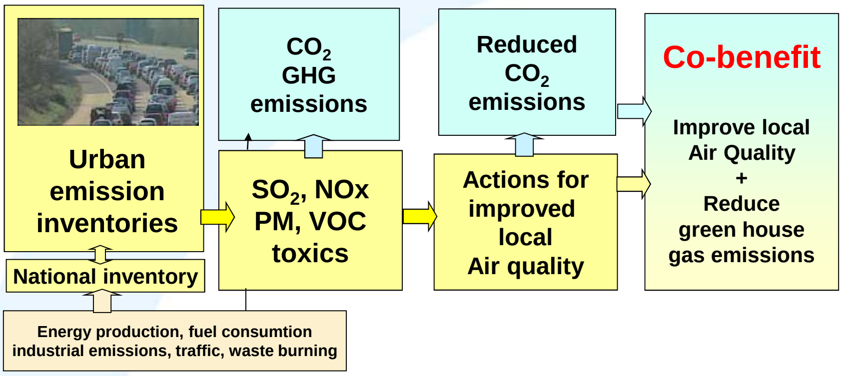
Co-benefit/co-control approach

Urban Air Quality Planning
+ Greenhouse gas reductions



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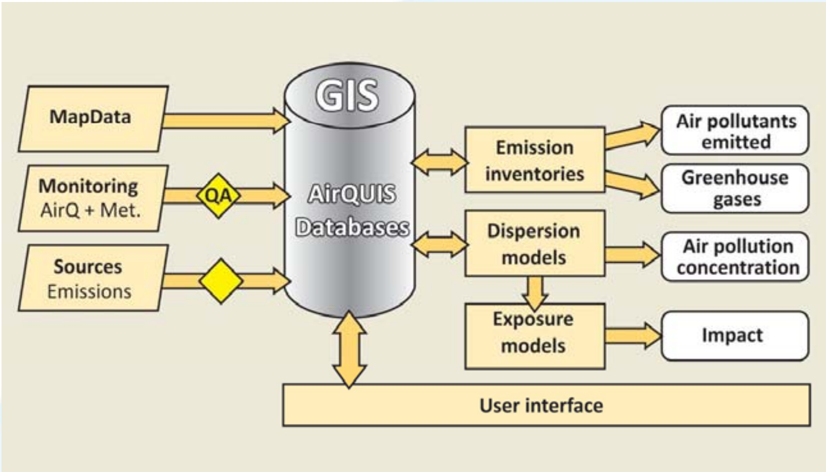
The NILU planning tool



Enable integrated planning !

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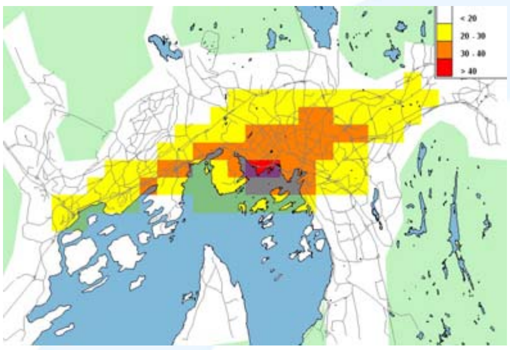
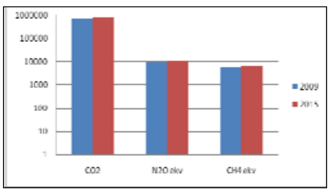
Scenarios Oslo, Norway



Area exceeding limit values for NO_2 , basic year 2015

Evaluated the exposure to people for alternative scenarios identified in order to reduce the air pollution impacts. GHG emissions Included !

Estimated CO_2 equivalents tons per year; 2009 & 2015



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Pollution exposure

Estimated number of people exposed to NO2 and PM10 in Oslo, 2009 and 2015

Oslo	NO2	NO2	PM10	PM10
Sources	Number exposed above hourly limit	Number exposed above annual limit	Number exposed above hourly limit	Number exposed above annual limit
All sources 2009	9 600	50 500	1200	<250
All sources 2015	2 400	19 000	4200	<700
Traffic emiss 2015	1 700	5 100	3000	<500
Wood burn 2015	0	0	0	0
Other sources 2015	0	0	0	0
All sources 2015, included actions	1 600	14 500	1900	<350

Limit values are similer to EU Directive 2008/50/EC (May 2008)

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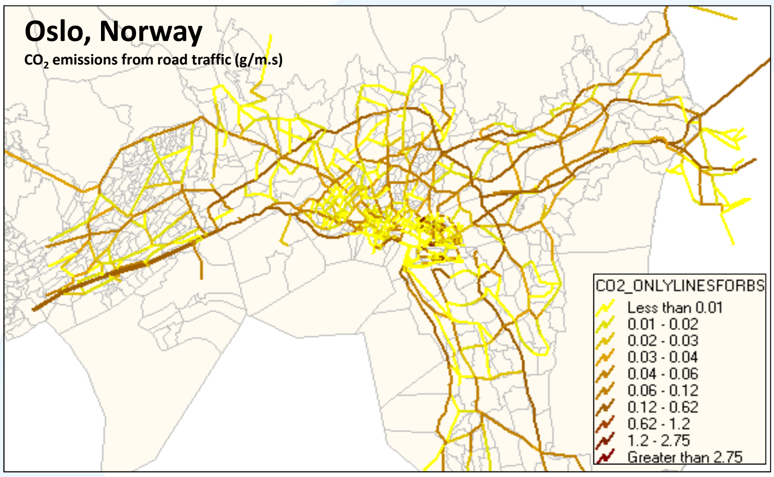
CO_2 emissions from traffic



Annual emissions Oslo: 1,5 mill tons CO2 (= 175 tons/hr)

Estimated for model area 750 000 tons

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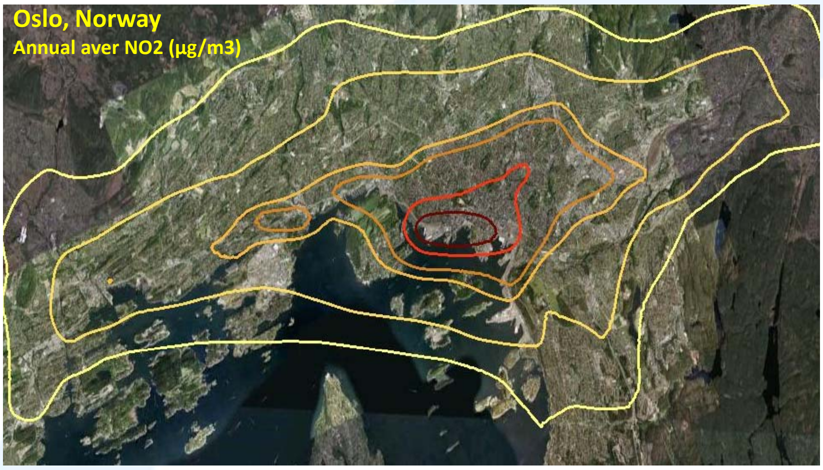
Model estimated concentrations



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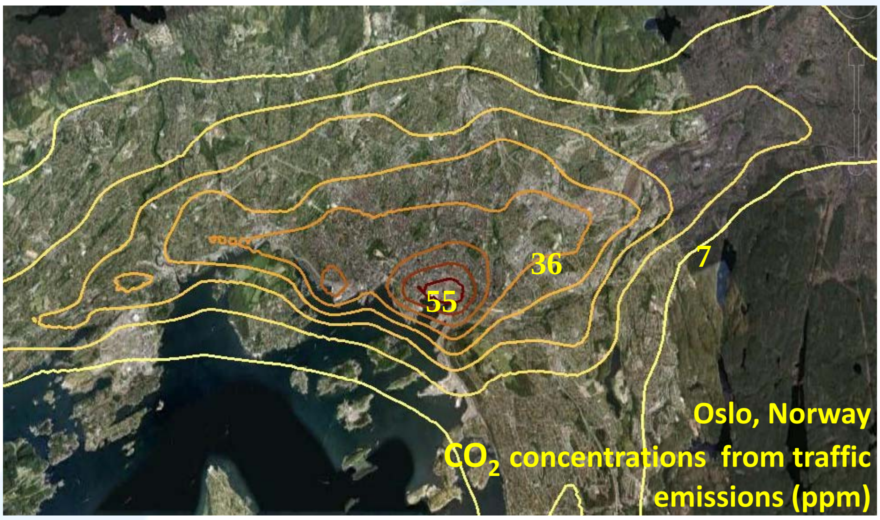
CO_2 contribution from traffic emissions



Background CO_2 = 380 ppm

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Actions to reduce impacts

1. Measures that reduce the number of vehicle kilometers:
   - Concentrated development of public transport hub
   - Home office, video conferencing, etc.
2. Measures that facilitate alternatives to car transport:
   - Public transport - better surface coverage, higher frequency, lower fares
   - Better arrangements for pedestrians and cyclists - walking and cycling routes
   - Park and ride
3. Measures to restrict car transport on selected routes / time periods
   - Travelers Payment (time-differentiated road pricing)
   - Low emission zones
   - Parking restrictions
   - Parking Fees
   - Car-free zones
   - Fuel Tax
   - Costs of workplace parking moved to the user
   - Maximum speed of the road network is set at 60 km / h
4. Cleaner wood burning and 5. Harbour emissions

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Effects of actions

	Actions	NO_2	PM_{10}	CO_2	Comments
Traffic actions	Prices, parking, public transport, mobility	++	++	++	Reduce car-km driven in Oslo
	Mobility planning	+	+	+	Long term policies
Vehicles	Non studded tires	0	++	0	Dust reductions, no CO2 effects
	Low emission zones	++	++	++	Immediate effects
	Eco driving	+	+	+	Long term effects
	Ban idling	+	+	+	Effect on CO emissions.
	Electric cars public transp	+	+	+	Long term
Roads	Speed limit reductions	0	++	0	Immediate effects.
	Road cleaning	0	++	0	Immediate effects.
	Reduce tunnel emissions	+	++	0	Clean road tunnel emisisons
Wood burning	Cleaner stoves	0	++	+	Long term effects.
Harbour emissions	Reduce ship emissions, change fuels	++	+	++	Immediate effects, also SO2 reduced.

++ *Positive effect = reduced impact*

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An integrated view on:

Carbon Capture and Storage (CCS)

Global benefits, local ???

Several alternative methods

Absorption with amine solution most appropriate technology to take out CO2 from exit gas.

Test Center in Norway will test the amine capture technology

NILU investigate the local impact of emissions of amines

Amines are in general caustic and corrosive and will therefore have a potential effect on the local environment.

Local impacts of CCS?

The amine group is a large group of chemical substances.

- ✓ **Long time exposure ; some of the amines can be carcinogenic.**
- ✓ **Vegetation impact of emissions – fertilization??**
- ✓ **Soil deposition: accumulation and degradation.**
- ✓ **Surface water: concentrations evaluated for accumulation in organisms**
- ✓ **The mass flux into the sea: investigate potential effects.**
- ✓ **Reactive amines may enter into the photochemistry of the atmosphere**
- ✓ **Odor problems: Amines have in general a strong and unpleasant smell.**

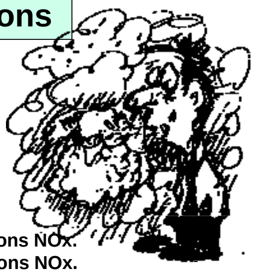
The consumption of energy used for the CO2 capture and the emissions that comes from the production of this energy should be estimated.

For the benefit of climate change:

From fossil fuels to Bio fuel

Reduce: CO_2 : and GHG
SO_2 : Sulphur emissions

Increased: PM :
PAH :
NOx :



Bio fuel based power plant Finland emits annually 440 tons NOx.
Gas power plant at Kårstø Norway emits annually 150 tons NOx.
Same size (400 MW), and both are equipped with cleaning device

Norway: Bio fuels instead of fuel oil reduces electricity consumption only 3-4 %

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In conclusion:

Integrate air pollution and GHG policies

✓Important to be able to assess both short and long term benefits of measures !
✓Particular sectors
- Transport, aviation and shipping
- Bio energy

✓Combined air pollution and climate change standards for road transport
✓Linking air pollution control to climate change mitigation.

Challenges:
Capacity building
Financing
Technology transfer

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Thank you !
Questions ???
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