REPORT

The Features of Non Technical Measures and Their Importance in Cost Effective Abatement of Air Pollutant Emissions

- Applied to Two Meta-Analyses

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Report Summary

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Summary

The overall purpose of this study is to compare the cost effectiveness of non-technical measures (NTM) and technical measures (TM). This requires an acceptable definition of NTM. There are two main questions discussed in this study in connection to the definition of NTM. Firstly, the distinction between technical measures and non-technical measures, and secondly the distinction between non-technical measures and policy instruments.

In many studies policy instruments are frequently seen as NTM, but it is important to stress the difference between NTM and policy instruments. NTM relate to the actual emission reducing actions, while policy instruments relate to the means used to enforce abatement options, and may lead to both TM and NTM. The definition proposed in this study to separate TM from NTM, is based on the changes of input and output when incorporating a measure, instead of only focus on changes in emission factors and activity data.

Based on the chosen definition of NTM, the project carried out two meta-analyses in the agricultural- and energy sectors. Since data on the shipping sector was not enough to allow a meta-analysis this sector was studied in a descriptive manner. The results of the meta regression for the agricultural and the energy sector included in this study give some insight on the cost effectiveness of NTM compared to TM. Depending on the nature of the subject i.e., a review of NTM, the data has been very scarce to allow consistent and representative results for all European countries; Most of the NTM studied have only one study as origin. Further, the reviewed studies are often related to the emissions of different pollutants, which have led to the use of different conversion factors in order run the meta regression.

Keyword

Cost effectiveness, air pollution, non-technical measures, integrated assessment modelling

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Summary

The overall purpose of this study is to compare the cost effectiveness of non-technical measures (NTM) and technical measures (TM). This requires an acceptable definition of NTM. In the literature review several definitions are used and there is a striking absence of theoretical motivation of the different definitions and classifications of NTM. The reason might be that the definition and classification themselves are irrelevant and just serves as an illustration. However, a suitable classification could potentially serve as a policy guideline to what type of NTM that can be considered as most cost effective and facilitate the incorporation of NTM into integrated assessment models.

There are two main questions discussed in this study in connection to the definition of NTM. Firstly, it is the distinction between technical measures and non-technical measures, and secondly the distinction between non-technical measures and policy instruments. In the studies policy instruments are frequently seen as NTM, but we do stress the importance to make a clear distinction between NTM and policy instruments. The reason is that the instruments are used by the government to make producers and consumers change their behaviour, and the NTM are the response to the instruments, and they might be of both technical and non-technical nature.

To make a clear distinction between TM and NTM is complicated. In this study a definition is proposed, which compare the changes of input and output when incorporating a measure, instead of only focus on changes in emission factors and activity data. Input and output reflect a firm's production where output is the produced commodity and input is the resources required for the production of the commodity. In an example with a car production facility, different types of measures are available. For a technical measure, such as a particle filter aiming to reduce emissions from car production, the output is the car, while input consists of labour, energy and raw material. The particle filter does not affect the mix or quantity of production input in order to produce the output to any larger extent. A NTM however, like a change in work routines that enables energy savings, will affect the quantity or the mix of input to production. It is this change that causes the emission reduction.

In the literature review quite a few attempts have been made to group and classify NTM. In the classification the measures often are regarded from a 'top-down' approach, relating the measure with the relevant policy area. In this study, a bottom-up approach is suggested which take the actual consequences of the measures in focus. Three classification groups are suggested: efficiency improvements, substitution and demand measures.

The distinction between non-technical measures, technical measures and policy instruments are visualised in Figure 1

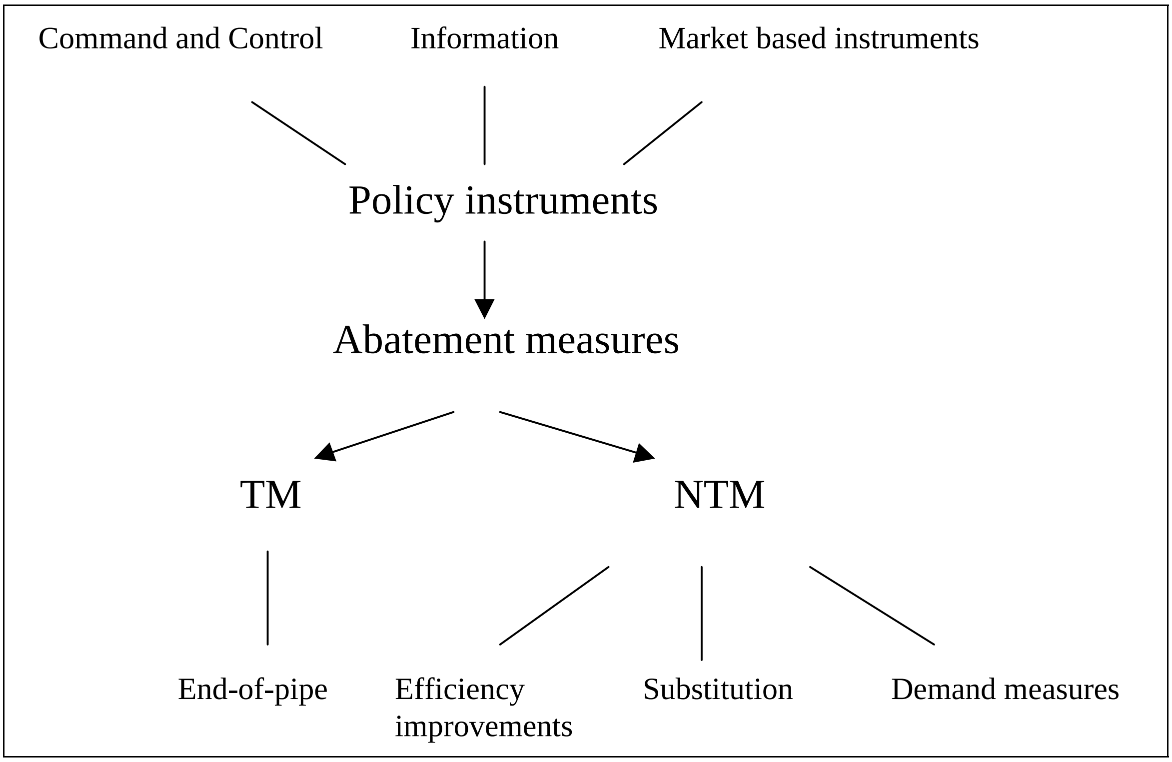


Figure 1 The distinction between policy instruments and abatement measures

Based on the chosen definition of NTM, the project carried out two meta-analyses in the agricultural- and energy sectors. Since data on the shipping sector was not enough to allow a meta-analysis this sector was studied in a descriptive manner.

The results of the meta regression for the agricultural and the energy sector included in this study give some insight on the cost effectiveness of the NTM compared to TM. In the agricultural sector an emission reduction of one percent using NTM would lead, *ceteris paribus*, to a cost saving of 1.56 percent. Since NTM may also lead to pure costs, the regression analysis shows that an emission reduction of one percent would lead to 1.35 percent increase in costs being specific to the agricultural sector. In both cases the results are highly significant.

In the energy sector an increase in emission reduction by one percent (other things being constant) would lead to a 0.98 percent of NTM savings. This is almost a one to one relationship. Further, the generated costs by NTM would increase by 0.71 percent if emission reduction of NO_X is one percent.

The results of the meta regression for the agricultural and the energy sector included in this study give some insight on the cost effectiveness of the NTM compared to TM. Depending on the nature of the subject i.e., a review of NTM the data has been very scarce to allow consistent and representative results for all European countries; Most of the NTM studied have only one study as origin. Further, the reviewed studies are often related to the emissions of different pollutants, which has led to the use of different conversion factors in order run the meta regression.

Contents

Abbreviation

ASTA	International and National Abatement Strategies for Transboundary Air Pollution
CAC	Command and Control
CAFE	Clean Air For Europe
CANTIQUE	Concerted Action on Non Technical Measures and their Impact on Air Quality and Emissions
CLRTAP	Convention on Long-Range Transboundary Air Pollution
ECCP	European Climate Change Programme
GAINS	Greenhouse Gas and Air Pollution Interactions and Synergies
GHG	Greenhouse Gases
HAM	Humid Air Motors
HFO	Heavy Fuel Oil
IAM	Integrated Assessment Modelling
IIASA	International Institute for Applied Systems Analysis
MDO	Marine Diesel Oil
MERLIN	Multi-pollutant, Multi-effect, Assessment of European Air Pollution Control Strategies: an Integrated Approach
NRCS	The National Resource Conservation Service
NTM	Non-Technical Measures
OLS	Ordinary Least Square
RAINS	Regional Air Pollution Information and Simulation
SCR	Selective Catalytic Removal
TM	Technical Measures
UN ECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme

1 Introduction

1.1 Purpose of the study

The overall purpose of this study is to compare the cost effectiveness of non-technical measures (NTM) and technical measures (TM). This requires an acceptable definition of NTM, that is broad enough but at the same time sufficiently restrictive to allow some kind of boundary control.

Based on the chosen definition of NTM, the project aims to carry out three meta-analyses in the agricultural-, energy- and shipping sectors. In the meta-analysis the cost-effectiveness of NTM and TM to reduce air pollution will be compared.

The study will also discuss the possibilities and constraints to incorporate NTM in Integrated Assessment Models (IAM).

1.2 Method

The main method in the definition work of NTM, is to carry out a detailed literature review. A number of models as well as other studies in this field are analysed and compared. The analysis together with long discussions, where several measures in different sectors are structured, provide the theoretical background for the work on a definition of NTM as well as the work on a suitable classification approach.

The data for the meta-analysis is collected from a number of studies and reports. The data contains actual emission reductions, cost-effectiveness as well as total costs. The regression estimates combine both technical as well as non-technical measures where the estimated results are given in elasticity form showing the impact of percentage changes in emissions reduction on percentage changes in costs.

1.3 Limitations

Since much work on NTM previous has been done in the transport sector only the agricultural, energy and shipping sectors are considered for meta-analysis. The transport sector is however discussed in the theoretical argument on NTM. Since data on the shipping sector is not enough to allow a meta-analysis this sector is studied in a descriptive manner. Furthermore, this study focuses only on emission reductions and costs as given by model calculations and actual abatement measures. Other aspects of the measures, such as 'measure applicability' and 'reduction potential', are outside the scope of this study.

1.4 The structure of the paper

This study is divided into seven chapters. In chapter 2 different initiatives to abate air pollution are discussed as well as the importance to take NTM into account in integrated assessment models.

Chapter 3 deals with different attempts to define and group NTM, and in the following chapter the approach used in this study is described.

The cost of implementing TM and NTM can affect different actors of the society, which is highlighted in chapter 5. In this chapter the importance of cost-effectiveness as well as economic efficiency are also discussed. In chapter 6 the main theory on meta-analysis is described as well as the results from the meta-analysis.

Finally, chapter 7 includes data about the relative importance of the measures in the study and the general conclusions together with recommendations for future work can be found in chapter 8.

2 Background

2.1 International initiatives to abate air pollution

The UN ECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) is an international instrument, established in 1979. The Convention aims to control the regional air pollution problems in Europe by establishing a broad framework for co-operative actions. CLRTAP sets up a process for negotiating concrete measures to control specific pollutants through legally binding protocols, most recently the so-called Gothenburg Protocol directed towards sulphur dioxide, nitrogen oxides, volatile organic compounds and ammonia in one joint strategy (Munthe et al., 2002).

In parallel with CLRTAP the European Union has in 2001 launched a programme to abate air pollution, the so-called Clean Air For Europe (CAFE). The aim of CAFE is to develop a long-term, strategic and integrated policy advice to protect against significant negative effects of air pollution on human health and the environment. This programme is the basis of the development of the Thematic Strategy on Air Pollution, which was adopted by the Commission in 2005 (http://europa.eu.int/comm/environment/air/cafe).

Air pollution strategies developed within the framework of CLRTAP and CAFE are mainly based on technical measures to abate air pollution for which the potential emission reduction and costs often can be estimated and used in IAM. More recently NTM have been put forward as an important complement to TM in future air pollution strategies.

2.2 The possibilities and constraints with non-technical measures

For the sake of reducing emissions and thereby their impacts on the general public and the environment, producers have been using different measures including both technical and non-technical where the most used ones have been the technical measures. However, since the use of technical measures has been based on ranking the option for abatement, starting by reducing emissions by using the cheapest measure, and then continuing with the second cheapest, etc., the last measures are the most expensive leading to higher abatement costs. Therefore, in the search for less expensive abatement measures NTM need to be considered.

Due to the nature of NTM, the potential and cost to implement them are in many cases difficult to estimate. Generally, since behavioural changes in many cases are required, the effects of these measures are quite intricate since they often involve complex human psychology. For instance, when people decide to choose a certain mode of transportation, they generally have a preference for a certain mode, but different thresholds when they will switch from one mode to another. Cost-benefit analysis, decision theory, surveys of users' preferences and experts' opinions can be needed to estimate the potential of these kinds of measures (Brand et al., 2000).

Due to the difficulties to capture the potential and costs of these measures in modelling exercises, they have only to a small extent been included in integrated assessment models. Since it is assumed that they will play a more important role in the future, especially in reducing emissions of greenhouse gases, there is a need to discuss both the possibilities and the constraints to include them in IAM and in future air pollution strategies.

2.3 Integrated Assessment Models

A number of models have been developed over the years in order to assess the environmental impact related to human activities. The models of greatest concern in this study are RAINS, GAINS and MERLIN. PRIMES and TREMOVE are also of interest as they provide background information to the simulations that are performed in RAINS and GAINS. A very brief presentation of the models is given bellow.

2.3.1 RAINS

The Regional Air Pollution Information and Simulation (RAINS) model is developed by the International Institute for Applied System Analysis (IIASA). It is constructed with a multi-pollutant, multi-effect approach. Air pollution effects on acidification, eutrophication, vegetation damage and human health and abatement costs are among the available results (Klaassen et al., 2004). The RAINS model uses scenarios for agricultural activities and energy use following projections on economic activities in order to calculate financial costs and environmental effects of emission abatement. The PRIMES model carries out the energy projections, which are used as exogenous variables. RAINS can estimate the cost for reaching specified emission levels or environmental targets by using country-specific cost calculations for pollution abatement (Amann et al., 2004). The model only considers TM in their cost calculations, but includes the effect of structural changes in the transport sector, by the use of the policy assessment tool TREMOVE.

2.3.2 GAINS

The Greenhouse Gas and Air Pollution Interactions and Synergies model (GAINS) is an extension of the RAINS model, and includes Greenhouse gases (GHG) (Klaassen et al., 2004). Though, there are some important differences between the models. Firstly, the GAINS model uses change in energy demand as potential GHG abatement strategies, while the RAINS model only uses energy demand projections as an exogenous parameter. Another difference lies in the calculations of emission reductions. In RAINS, the cost curves for emission reduction are calculated on a national- and pollutant-specific level. The emission reduction levels are then set following the cost curves. In GAINS, the activity level of the abatement measure is first decided, and the emission reduction of all pollutants and total costs for the region is a result of this activity level. The decision on the level of activity levels for different techniques is then set to minimise total costs and still achieve emission targets. The main difference is that GAINS chooses to minimise the costs for abating all pollutants, while RAINS minimises the costs for abating the pollutants separately. In GAINS, specifying the emission level precedes the calculations of total as well as marginal costs (Klaassen et al., 2004).

2.3.3 MERLIN

Multi-pollutant, Multi-effect Assessment of European Air Pollution Strategies: the Integrated Approach (MERLIN) is a model developed simultaneously with the RAINS model. MERLIN includes macro-economic effects and cost-benefit assessment in the optimisation, which are not included in RAINS. This means that economic evaluation of the benefits of reducing the environmental impact of air pollutants is included in the search for optimal emission controls. MERLIN also uses a different approach to emission abatement, which enables inclusion of NTM in the emission abatement calculations (UCL, 2004). The inclusion of NTM in MERLIN is further discussed in the next chapter.

3 Definitions of NTM

There is to date no consensus upon the definition of NTM and the distinction between TM and NTM. The name technical measures imply that the measures are technology dependent. On the other hand, NTM despite their names are not completely independent of technology changes, but they are rather geared towards changing the behaviour of technology users. In the available literature NTM are often treated from several different viewpoints and there will always be borderline cases irrespective of the chosen definition. The most important discussions are summarised in this chapter and the chosen definition used in this study is discussed in chapter 3.3.

3.1 Technical and non-technical measures

3.1.1 Changes in emission factors and activity data

A commonly used definition of the two types of measures is based on changes of the emission factors and the activity data when implementing the measures. TM result in changes in the emission factors while NTM comprise measures which have their main effect on the level of sectoral activity. When shifting oil for bio-fuel, for instance, the activity level for oil use is changed, but when installing a filter on a factory chimney the activity level remains constant, but the emission factor is decreased.

In certain cases, the choice of activity unit is crucial. In the case of eco-driving, for instance, the choice of unit on activity data can imply different results. If the activity is measured in vehicle km, it will not change even if the driver drives more environmental friendly (eco-driving), but if the amount of energy used is the unit used for activity data; it will decrease for the same distance. If the activity data is measured in km travelled, entail that eco-driving will be called a technical measures as it only affect the emission factors (Ribbenhed et al., 2005).

Furthermore, there are cases where a measure acts both on the activity data and the emission factors. This is often relevant when discussing substitution processes, which often cause both the activity level and the emission factor to change. Fuel substitution can involve shifting from a fuel with poor environmental and energy characteristics into a fuel with good characteristics on both. This would lead to a reduction in emissions both due to less consumed energy as well as lower amount of pollution produced per energy unit. Some aspects of this will be further discussed in chapter 4.

RAINS discuss in terms of emission factors and activity data, but do not specify a distinction between TM and NTM. The discussion is based on the distinction between the different emission control options behavioural changes, structural measures and technical measures, as is further discussed in chapter 4.

3.1.2 Prices and demand

TREMOVE (de Ceuster et al., 2005) calculates transport emissions and activities from changes in demand via changes in prices and elasticities. No specific distinction is made between TM and

NTM in TREMOVE. The distinction between measures is focused on how they affect prices and demand.

MERLIN also uses a distinction between TM and NTM in the model. From a modelling approach TM and NTM are separated by the same difference as used in RAINS, TM affects emission coefficients and NTM affects activity levels. MERLIN also uses an economic approach to TM and NTM, and separates the measures with respect to whether they have effect on the supply side or the demand side of produced commodities. MERLIN recognises that TM can affect both emission factors and activity levels in principle, even though only changes in emission factors are modelled. The activity levels should be affected by increases in marginal cost of production, following the implementation of the TM. This motivates the approach 'supply side measure'. The activity data should be affected since the increase in MC may decrease the equilibrium production level for the commodity considered, and thus change the activity data for that commodity. NTM mainly affects the demand side and can according to MERLIN thus be seen as 'consumer measure'. The measures mentioned are mainly commodity price related and are considered to change the equilibrium production of a commodity through a shift of the demand curve. The consequence is that NTM affects emission only through changes in activity levels. An important aspect of the distinction is that NTM only considers commodities that enter the consumers' final utility function, thereby clearly separating between supply and demand. This means that all commodities that are consumed but not *directly* represent any utility must be translated into the final commodity that is represented in the final utility function. Examples of 'final consumption commodities' are heating services and personal mobility, while the commodities electricity, heating apparatus, motor fuel and motor vehicles are considered as input to these final consumption commodities (UCL, 2004).

An important implication of the above distinction of consumer commodities is that fuel shift will be considered to be TM, since fuel shift does not change the consumption of the final commodity 'heating service' or 'personal mobility'.

3.2 Non-technical measures and policy instruments

In the available literature, there is not only a lack of consensus regarding the definition of NTM in regard to TM, but also to policy instruments. The literature review makes clear that NTM, frequently, are defined as policy instruments used to implement various emission abating activities. Though, later work on NTM has stressed the importance of separating measures and instruments since a market based instrument can have a pollutant abating effect both via technological improvements as well as behavioural changes (UCL, 2004). For example, a measure can be a transport shift from passenger cars to public transport, while the instrument would be increase in road taxes. Three literature examples have been chosen in order to illustrate the different manners in which NTM and policy instruments have been discussed

The first example is the definition of NTM in the 'Concerted Action on Non Technical Measures and their Impact on Air Quality and Emissions' (CANTIQUE) partly developed in collaboration with the Auto Oil II programme. In CANTIQUE, 'all transport measures other than general fiscal measures and prescriptive measures affecting vehicle and fuel technology supply' are defined as NTM. These would include public transport and inter-modality, traffic management, efficient road freight transport and other measures influencing drivers' and travel behaviour (Brand et al., 2000).

The Auto Oil II programme, which like CANTIQUE basically studies the transport sector, defines NTM as the measures that change the use of transport, for instance, the choice to travel or transport goods, point of time to travel, choice of vehicle etc. This definition includes market-based instruments. Examples of measures are, for instance, improvement of traffic flow by increased road capacity, time and vehicle differentiated parking charges and urban road pricing etc, which are simulated in TREMOVE (European Commission, 1999).

The third example is taken from MERLIN (UCL, 2004), that clearly points out that it is important to separate measures from policy instruments. The general idea in MERLIN is that an 'instrument' is the governmental tool or policy lever, while the non-technical measure is one possible implementation of the instrument. This distinction is motivated since the implementation of an instrument often leads to both technical and non-technical measures.

3.3 The definition used in this study

In this study a clear distinction is made between NTM and policy instruments:

NTM relate to the actual emission reducing actions, while policy instruments relate to the means used to enforce NTM and TM, as a policy instrument may lead to both TM and NTM.

In the transport sector, for instance, the instruments include infrastructure changes, information campaigns as well as road pricing and congestion charges etc. Examples of NTM in the transport sector are modal shifts from private car to public services and cycles, as well as less transportation of people and goods. In the energy sector taxes and limitation in the use of small-scale combustion can exemplify policy instruments, while fuel switch as well as energy conservation through better insulation, reduced hot water by in households and more energy efficient production in the industry are good examples of NTM. In short, NTM is considered to be one of the possible responses to the implementation of a policy instrument.

To make a clear distinction between TM and NTM is not an easy task. The suggested definition uses the terms input and output instead of emission factors and activity data. Input is the resources required for the production of the commodity. Output reflects a firm's production. Having established this distinction, some examples of TM and NTM will be given. In the case of a car producing facility, a particle filter that reduces emissions exemplifies TM. In this example the output is the car, while input consists of labour, energy and raw material. The particle filter does not necessarily affect the mix or quantity of input in order to produce the output. A NTM however, like a change in work routines that enables energy savings, will mainly affect the quantity or the mix of inputs. It is this change that causes the emission reductions, since different inputs may cause different amounts of emissions. Another type of NTM that alters the input mix / level, is to lower the final demand for the output, and thereby lowering the required input. The distinction between if the measure affect the original input or not is the key element of the proposed distinction between TM and NTM.

A suggested definition:

A NTM reduces emissions by changing the mix or quantity of input to production, without the necessity of additional input. This is in contrast to TM, which requires the addition of new input (abatement equipment) in order to reduce emissions.

Of course the costs of the measures can affect the marginal cost of production, which in turn can affect the optimal production of output. But if the cost effects are considered in the process of defining TM / NTM, the situation will become more complex and TM / NTM could get more difficult to distinguish from each other. Still, the effects from increased marginal costs should be considered when calculating emissions and costs.

If NTM is defined as changes in input mix or level, this could facilitate the discussion of certain measures. Eco-driving will be used as an example. In this case, activity data can be considered as either driven km or required energy. If the activity data is considered as driven km, the activity data will not change when implementing the measure, and the measure would thus be defined as a TM. If the activity data is defined as required energy, the activity data would change, and the measure would be defined as NTM. So the definition of eco-driving is dependent on which activity data that is used. But, by using input and outputs in the case of eco-driving, the measure can easily be recognised as reducing input, and the measure would be considered as an NTM.

Another difference between the economic definition suggested in this study (input/output) and the one used in the MERLIN project (supply/demand), is that the input / output terminology can be adopted to all polluting sectors, while the supply / demand terminology differs between consumers and producers.

4 Classification and grouping of NTM

The purpose of dedicating a chapter to the classification of measures is to clarify the concepts used and to suggest a classification method that suits both the requirements of IAM as well as the scientific work on other abatement measures than 'end-of-pipe' solutions. If one were to have a common approach on how to treat NTM regarding effects and costs, the possibility to use results from NTM surveys and reports into IAM could increase substantially.

This chapter starts with a brief presentation of how TM and NTM are included in different models used today. This presentation illustrates that many different approaches can be used when working with NTM. The next part analysis the reasons to different approaches. Finally, one classification approach is chosen and motivated, and the consequences of this classification approach are briefly discussed.

4.1 Examples of NTM classification

There are a number of different types of classification approaches used to describe possibilities to abate emissions. For instance, in RAINS (Amann et al., 2004), an initial separation of emission-reducing options is between behavioural changes, structural measures, and technical measures. However, the measures actually modelled in RAINS are only technical measures (a few NTM in the agricultural sector), such as 'end-of-pipe' technologies. It is the technical measures that are used in the emission calculations via their effect on emission factors from production.

The other emission reducing options recognised by RAINS, behavioural- and structural changes, are set as exogenous variables in the model. Exogenous variables have a numerical value that can not be changed within the model, so in order to study behavioural- and structural changes in a RAINS setting, different sets of exogenous variables have to be supplied to the model. This is equivalent to that different scenarios have to be developed in order to study behavioural- and structural changes. Behavioural changes are specified in RAINS as reduction in emissions due to reductions in "anthropogenic driving forces". These driving forces are represented by a number of policy instruments, amongst them regulation and economic instruments. Furthermore, the driving forces also include autonomous changes, which can be considered as caused by changes in preferences. The changes in preferences may ultimately result in lower demand for the polluting activity. Structural changes are measures that keep the level of societal service (energy consumption/production) constant but vary the polluting activities. Examples of such changes are fuel shift and energy conservation/efficiency (Amann et al., 2004).

In GAINS, the main classification between behavioural changes, structural and technical measures is the same as in RAINS (Klaassen et al., 2004). But unlike RAINS efficiency improvements and fuel substitution are included in the model as possible measures, since much of the GHG abatement options are to be found in these structural measures. Lower final demand measures are still not considered.

In an early version of the CANTIQUE project (UOC, 1999), a distinction is made between two ways to classify NTM. One classification approach focuses on the **transport field** in which the measure is applied; the other approach classifies the NTM according to the relevant **political field**, in which the NTM acts. In the way of presenting the NTM, the classification of measures from a transport field approach should constitute the groups operational-, strategic- and demand measures. This classification is also adopted by the DG Environment /European Commission in the report 'Economic Evaluation of Emission Reductions in the Transport Sector of the EU' (Sternhufvud & Forsberg, 2003). In CANTIQUE, the operational measures affect the energy use and emissions per vehicle-km. The strategic measure includes optimisation of vehicle-use in relation to a specific transport demand. Demand measures affect the actual demand for travel and transport. From a political field approach, the classification starts in different means of enforcing these measures. These methods are called 'policy levers'. The main groups of policy levers are pricing policy taxes, regulation as well as infrastructure, information, voluntary agreements and institutional frameworks. One can consider the classification to reflect the political institution that would enforce the emission abating measure (UOC, 1999).

4.2 'Top-down' or 'Bottom-up' approaches

The classification efforts made in the texts reviewed above reveals that the measures often are regarded from a 'top-down' approach, relating the measure with the relevant policy area / implementation sector. 'Top-down' and 'Bottom-up' are two terms that illustrate from what perspective a phenomena is regarded. Top-down indicates a large scale starting point while 'bottom-up' indicates a small scale starting point. In this study, by saying that a measure is regarded from a 'top-down' approach indicates that the measure is regarded from the political view, where the 'idea' of a measure can be formulated. A bottom-up approach starts from the other end, with the actual consequences of the measure in focus. An effort to illustrate the differences between 'top-down' and 'bottom-up' approach is shown in Table 1. The examples of mechanisms, instruments and measures are not to be considered as corresponding to each other, they serve as examples only.

Table 1 Top-down versus bottom-up approach

Top-down →		← Bottom-up
MECHANISM →	**INSTRUMENT →**	**MEASURE**
Enforcement	Pricing policies	Efficiency
Reward / punishment	Taxes	Substitution
Normative	Regulation	Demand
	Infrastructure	
	Information	
	Voluntary agreements	
	Institutional frameworks	

The terms behavioural and structural, (RAINS), operational, strategic and demand (CANTIQUE) and the term 'demand side' (MERLIN) are all characterized by the policy aspect of the measure. This is, of course, very relevant for the implication of policy mechanisms in the international air quality work, but can be less ideal from other aspects. If one would like to focus on the actual emission reduction, the subgroups in the RAINS and GAINS behavioural and structural measures must be observed (Klaassen et al., 2004; Amann et al., 2004). The separation of measures into 'lower final demand', 'increased fuel conversion efficiency' and 'fuel substitution' has a clearer 'bottom-up' approach since they indicate in what way the emissions are actually being reduced.

4.3 Proposed classification of NTM

The proposal on a common classification suited to this study's definition of NTM is adapted from the classifications in previous work presented in 4.1. The proposed classification originates in the classifications made for the transport sector, both since that classification of measures seems well adapted to assessment modelling and also since almost all work on NTM originates from that sector.

The proposed classes of NTM are efficiency improvements, substitution and demand measures, which are relevant from a 'bottom-up' approach. This classification approach is to some extent implemented in IAM, but it can still be important to advocate this classification since many studies on abatement NTM use 'top-down' classification approaches on NTM. This 'top-down' approach can make it more difficult than necessary to implement results from NTM studies into IAM. A comparison of the effect of the different NTM classes suggests that efficiency improvements and substitution both directly affect the input mix / level, while the demand measures primarily affect the output levels and secondarily the input. None of the different classifications violates the suggested distinction between TM and NTM.

In order to clarify the difference between the different classes, three examples are given. An efficiency improvement will reduce the use of the considered input. A substitution measure will reduce the use of one input while increasing the use of another. Finally, lower demand on output will automatically lower the input use. As a reminder, TM would require the addition of an input (abatement equipment) in order to enable emission reductions, the original input use and input mix can be kept constant in a TM.

When adjusting these ideas into what could be useful in the discussion on implementation of NTM into IAM, it must be pointed out that the input/output concept strictly relates to production activities, while the concepts of emission factors and activity levels used in RAINS more relates to polluting activities. These polluting activities can sometimes be similar to input, while they in other cases are similar to output. This makes a direct translation between input/output and emission factor/activity data difficult to perform. If activity data only related to output, substitution- and efficiency NTM could be similar to changes in emission factors of production, not activity levels. This 'production activity'- characteristic would make the suggested substitution and efficiency classes of NTM to behave in a similar way as TM, when described by MERLIN (UCL, 2004). This is of course contingent that the activity data is expressed as output, not input or emissions. Demand measures however, do affect the activity data rather than emission factors, regardless of whether the activity data is expressed as production or polluting activity.

This discussion on definition and classification of NTM is so far mostly related to pollution originating from production, even though many NTM are directed towards the general public. When discussing NTM concerning the general public, terms like input / output can be considered as inappropriate, so another terminology is used. NTM adopted on the general public is further discussed in Appendix I.

Another way to classify the measures is shown in Appendix II, which is based on the result from the ASTA / UNECE TFIAM workshop '*The importance of Non-Technical Measures for reductions in emissions of air pollutants and how to consider them in Integrated Assessment Modelling*' (Sternhufvud & Åström, 2006).

5 Calculation of reduction cost

At the producer and consumer level both TM and NTM have been used to abate emissions and the use of each of them has been dependent on their abatement costs. Estimating the costs of the measures, especially NTM, is not a trivial exercise as these reduction costs are in many cases composed of many costs. Discussing reduction costs including TM and NTM may give some hint on whether NTM are more cost effective than TM or not.

5.1 Costs related to emission abatement

In general, there is a lack of a standard definition of the costs related to emission abatement. The most discussed ones when studying externalities and to mitigate their impacts; are control costs, administrative costs and damage costs. Some of these costs are born by the transactors in the market i.e. producers and consumers, other costs are related to policy makers and policy instruments. These costs are listed in Table 2.

Table 2 Environmental costs

Producer	Consumer	Policy maker	Environment and general public
Control cost	Control cost	Administrative cost	Damage cost
Abatement cost	Abatement cost	Rule making cost	
Transaction cost	Transaction cost	Implementation cost	
	Welfare lost	Enforcement cost	
		Transaction cost	

Control cost: The control costs for the producer includes both transaction costs and abatement costs. The abatement cost for measures are often indicated by the investment costs, fixed operating costs and variable operating costs and is often restricted to end-of-pipe controls. These costs might seem easy to estimate, but this is not always the case.[1] The transaction costs include, among others, monitoring and controlling the emission abatement

For the consumer the control costs may take different forms. It can be direct costs such as in the case of installing a catalytic converter, but it might also include welfare lost. Abatement measures, especially NTM might in some cases imply non-financial costs for a consumer. Examples of such costs might be additional time spent or experienced reduction in welfare due to inconveniences caused by lower indoor temperature, waste sorting or using a bicycle instead of driving. The discussion on what type of costs that should be considered is of interest since many non-technical measures can have a substantial impact on non-financial costs for the private consumer. By choosing to ignore these types of costs, NTM might appear more favourable than would be the case if the welfare lost was included.

Administrative costs: The administrative costs include the cost to choose policy instruments to tackle pollution, to enter them into force as well as monitoring and enforcement. The costs for the

[1] For example, at the time of development of a pollution charge on NO_x emissions introduced in Sweden in 1992, average abatement costs were estimated at SEK 40 (approximately $5.50) per kilogram. The actual cost turned out to be less than one-quarter of that figure, resulting in substantial over-compliance (Swedish Ministry of Environment and Natural Resources, 1994).

government are not negligible and might include (http://enduse.lbl.gov/SharedData/lewisandclarktalk.ppt):

- "Research costs" which are *ex-ante* studies to investigate the external costs i.e. the damage cost to the general public and the environment;
- Rule making cost to discuss externalities with interest groups and to choose the instruments to tackle the externalities; ex-ante analysis of the instruments;
- Administrative implementation costs in order to ensure correctness of environmental regulation;
- Enforcement costs for monitoring and enforcement of the regulations;
- Information costs to highlight the effect of externalities and the measures to be used to mitigate the impacts;
- Evaluation costs of the instruments. This is related to *ex-post* analysis of the environmental instruments to assess their efficiency. This valuation is however rare.

Damage cost : Damage costs are also referred to as external costs. These costs are related to the damage of externalities on the environment and the general public. These costs are characterised by a dominant level of uncertainties.

As discussed above environmental costs include several types of costs. Some of these costs are considered while studying cost effectiveness and others are considered when analysing the economic efficiency of different instruments. However, sometimes these costs are mixed up or they are referred to when it should not. The knowledge about all the costs is of great importance when discussing policy instruments. A discussion about different policy instruments and the theory about how to obtain optimal instruments is further discussed in appendix II.

5.2 Transaction costs

The discussion above highlights a diversity of costs to abate emissions. Also the transaction costs can be separated into two groups; transaction costs for the producers and transaction costs for the policy makers.

According to traditionally economic theory the transaction costs for the producer, which include resources that have to be used to carry out a market transaction, i.e. identifying market partners, negotiating, monitor and control its execution (Coase, 1937), should be separated from the abatement cost and not be included in the discussion of cost effectiveness. In most studies they have been ignored, which is also the case in the integrated assessment models RAINS.

Ostertag (1999) has studied the importance of transaction cost for the producer when raising energy efficiency. In the study the energy saving potentials to reduce CO_2 is compared with the transaction cost. The study has shown that the result of a systematic integration of transaction costs of energy efficiency technologies and standard technologies is not definitely clear. The reasons to this uncertainty are (Ostertag, 1999):

- Even if there are transactions costs there may exist little or no transaction cost differences between competing solutions;
- Transaction costs for improving energy efficiency may only be marginally higher than "business as usual" transaction costs;
- Transaction costs may be reduced through economies of scale and learning effects;

- The costs of policy instrument or an institutional set-up is not simple additive to other transaction costs, and the cost of the instruments might even be equilibrated by the transaction and production cost savings they generate.

As NTM often require behavioural changes, they need to be accompanied by policy instruments to be realised. The transaction costs for the policy makers are also important to highlight. This issue has also been examined quantitatively using data collected by the National Resource Conservation Service (NRCS). Transaction costs are found to be a significant portion (38 percent) of overall conservation costs. This provides strong support for including these costs in economic evaluations of alternative policy instruments, but also in the discussion which costs to include in IAM (McCann et al., 2000).

While the importance of transaction costs has been recognised in the theoretical literature, the fact that they are not incorporated in empirical analyses means that, in effect, these costs are given a zero value.

6 Meta-analysis and meta regressions: the cases of the agricultural, energy and the shipping sectors

6.1 Introduction

The emissions from the agricultural sector have, so far, not been of any great importance in the European air quality work. However, recent findings in the international scenarios developed under the EU CAFE programme show that the agricultural sector will increase in relative importance regarding emissions of acidifying and eutrophying pollutants (Amann et al., 2004). The measures found in the agricultural sectors differ somewhat from the measures commonly found in other sectors such as transport and energy sectors. There are, however, opportunities even in this sector to reduce emissions in a cost effective way using both TM and NTM where the latter measures are shown to be less expensive.

In the energy sector, the marginal costs to further reduction of emissions are getting more expensive since most of the cheap measures have already been implemented. However, there are opportunities to use non-technical measures that are more cost effective than the technical measures.

The shipping sector is regarded as a sector where cost effective abatement measures are available. These measures are, as for all sectors, both technical and non-technical in their nature. Furthermore, the shipping sector is increasing in relative importance regarding emissions of sulphur and nitrogen according to the latest model calculations (Amann et al., 2004). The sector has not been subject to strict regulations regarding air emissions (Kågeson, 1999), but lately, the 'Sulphur Directive' 1999/32/EC, and the IMO adoption of the North Sea SECA limits the fuel sulphur content in the Baltic and North Sea (www.seaat.org). However, the fact that the land-based emission sources has been subject to regulations for a long time while the requirements in the shipping sector traditionally have been relatively low, enables cost effective measures to be taken in the shipping sector.

Although the specific characteristics of the agricultural, energy and shipping sectors are different, the objective of this study is to evaluate the use of NTM as a complement to TM in the search for the more cost effective measures to abate emissions. Previously in this report, a suggestion on which characteristics that distinguishes TM from NTM was presented. This distinction is used to separate the data collected into a TM group and a NTM group in the analysis of the relative cost effectiveness.

This chapter is organised as follows. Section 6.2 is about meta-analysis and meta regression. In sections 6.3 and 6.4 the agricultural and the energy sectors, respectively are analysed using a meta regression to study the impact of NTM and TM to reduce emissions as well as to compare their cost effectiveness. In section 6.5 only a descriptive analysis of the shipping sector is carried out, due to lack of data. Possible measures and their cost effictiveness are discussed.

6.2 Meta-analysis and meta regression

The general definition of a meta-analysis is a study of other studies. There are different ways to carry out a meta-analysis. To carry out a literature review is one possibility; another solution is to carry out a regression analysis.

In general, literature reviews are instrumental in summarising the contending economic theories and in framing the remaining issues at stake. Nonetheless, there remains a great deal of subjectivity in literature surveys. The reviewer often impressionistically chooses which studies to include in his review, what weights to attach to the results of these studies, how to interpret the results, and which factors are responsible for the differences among those results (Jarrell, 2005). Additionally, literature reviews are often used as a source of values that can be adapted and used in other studies. This is often done when resources are limited to conduct specific studies and the use of values estimated in other studies may be "borrowed", adapted and used in the actual study.

6.2.1 Meta regression analysis

On the other hand "meta-analysis is a research method to synthesise previously obtained research result. It is best seen as a statistical approach towards reviewing and summarising the literature" according to Florax et al. (2002). Meta regression is a form of meta-analysis, but is above all meant to be a tool to scrutinise empirical results related to economics and other issues. The meta regression analysis:

- are rather objective depending on the fact that meta regression is based on statistical analysis including values from different studies;
- allows a ranking of impacting variables. Contrary to literature reviews, meta-analysis as well as the use of regression analysis allows analysis of which variables have more impacts than others by use of dummy variables in the regression analysis. The dummy variables are used to account for seasonal effects, structural beaks or other covariates;
- allows correlation analysis between the dependant and the independent variables.

In general regression analysis includes a variety of estimation techniques that may be used in the meta regression analysis. The meta regression may use "Ordinary Least Square" (OLS), which is the simpler version of the least square method for a linear regression analysis. An example of the standard formulation is shown in (Equation 1:

$$G = c + \alpha p + \beta D + \varepsilon \qquad \text{(Equation 1)}$$

G	dependant variable
c	constant
p	independent variable
D	dummy variable
ε	residual
α	coefficient
β	coefficient

This model can be estimated in different ways:

- a simple way where the coefficients are parameter estimates;
- a semi logarithmic form where the coefficients are commented as percentage changes;
- a logarithmic form where the coefficients are commented as constant elasticities.

Savings
Every measure and related data is based on annualised values where the negative values depict savings. These savings often originates from efficiency improvements and are depicted as 'NTM saving' in the analyses. NTM savings and NTM costs are presented separately due to constraints in the analysis method used. This is separation is done both for the agricultural and the energy sector.

6.3 The agricultural sector

The measures found in the agricultural sectors differ somewhat from the measures commonly found in other sectors. The main pollutant from an acidification and eutrophication point of view in the agricultural sector is NH_3, and the main GHG emissions originate from emissions of N_2O and CH_4. Nitrogen pollution from the agricultural sector can act both through air emissions as well as emissions to soil water through leakage of nitrogen.

6.3.1 Literature Review

The data used in the meta-analysis is gathered from a number of studies and reports. The data contains actual emission reductions and total costs. The meta-analysis on agricultural is based on data from the following studies: Webb et al (2005), DEFRA (2004), Bates (2001), and Cowell & Apsimon (1998). In addition, data on abatement measures is gathered from the web-version of RAINS (http://www.iiasa.ac.at/web-apps/tap/RainsWeb/). The data used in the meta regression on the agricultural sector mainly originates from model calculations. Examples of model used for the model calculations are NARSES (Webb et al., 2005; DEFRA, 2004), and MARACCAS (Cowell & Apsimon, 1998). Bates (2001) uses literature review from earlier studies as a base for the cost calculations of abatement measures. IIASA uses their own calculations that are developed by the collaboration with the UNECE expert group on the subject.

A major part of the data used in the meta-analysis is from agricultural model calculations such as the MARACCAS model in Cowell & Apsimon (1998). In the agricultural sector it is also important to study measures' effect on other emissions, for instance, N_2O (Brink, 2004). This is also pointed out by Hasler (1998), who stress that abatement of agricultural emissions requires a 'whole-system'-approach, considering the correlation of effects between different abatement measures on a farm-scale level. This complex aspect makes the cost effectiveness more difficult to estimate for separate measures (Webb et al., 2005).

6.3.2 Data description

The data from the RAINS model is included in the regression as a comparison between the NTM data from the other studies and what is generally considered as technical measures (http://www.iiasa.ac.at/web-apps/tap/RainsWeb/). The data originates from the German CP_CLE baseline scenario. Germany is arbitrary chosen with the purpose of representing a standard situation for a European country. The used set of data for the agricultural sector from RAINS is presented for the year 2015, since no data sets from any earlier year was available. The distinction between TM and NTM has been performed in accordance with the distinction suggested in this report (chapter 3), so there are a number of measures from other data sources than RAINS that are considered as TM in the regression as well.

The regression is performed on emission reductions, for which we have emission reduction estimates and corresponding costs. The raw data is presented as either ammonia reductions or reduced nitrogen reductions to water (8 measures) or air (59 measures), or as reductions in nitrogen fertiliser use (18 measures). If more data would have been available, separate analyses could be performed. But given this constraint on data availability, all measures included in the analysis consider the reduced amount of nitrogen emitted to air or used as fertiliser. The data on fertiliser use also reflects changes in nitrogen emissions, but the form of these emissions is often site-specific and hard to generalise. The correlation between air and water emissions is also often site-specific. If one were to convert the reduction of emissions and fertiliser use to a common unit, generalisation would be required as well as the use of some sort of conversion factor. But the use of a conversion factor is not recommendable in regression analysis since it may lead to multi-colinearity, and generalisation in this area is connected with large uncertainties.

The data in the literature is often presented in a number of different currencies and for different years. It has therefore been recalculated to $€_{2000}$. A number of studies did not specify which 'currency year' that was used for monetary estimations. For these studies, the journal submission year, or the publication year, is used for the transformation to $€_{2000}$.

The measures included in the regression are presented in Appendix VI.

6.3.3 Regression results

In order to study cost effectiveness and to compare TM and NTM a meta regression has been run. The results are shown in Table 3 where the dependant variable is emission reduction, and it relates to the costs or cost saving implied by emission reduction. One would, however, argue on the use of abatement cost as a dependent variable. Nevertheless, since it is the emission reduction implied by the measures that is the cause of the reduced cost this is conducted as such as in the case of Quinet (2004). However, for the sake of comparison we run alternative regressions where the dependent variable is emissions reduction and the independent variable is cost.

As shown, an emission reduction of one percent using NTM would lead, *ceteris paribus,* to 1.35 percent increase in costs being specific to the agricultural sector. The results are highly significant. In the case of NTM costs saving the estimated elasticity is 1.56 and highly significant. However, since the number of observations is very small i.e., 14 the results are not presented on the table but they are discussed here in order to give insight on the magnitude of the elasticity.

Table 3: Cost effectiveness in the agricultural sector.

	NTM cost	TM cost
Variable	Estimate	Estimate
Emission reduction	1.35	1.08
	(13.98)*	(7.16)
Adj R^2	0.89	0.89
Number of observations	23	41

*The values within the brackets are the t-values.

In the case of TM some of the figures used for the estimations are based on cost-effective measures used in the RAINS model. For NTM, a more varied data regarding cost-effectiveness is used. This could partly explain the relatively low estimate (1.08) of TM cost as compared to NTM cost and saving. As shown in the table the parameter estimate is highly significant. Hence, an increase of emission reduction by one percent would lead to increase costs by 1.08 percent for TM.

On the other hand if the dependent variable is emission reduction and the independent is cost the elasticities are highly significant. For NTM saving the elasticity is estimated to be equal to 0.47. In the cases of NTM cost the elasticity is equal to 0.47. For the TM cost the estimated elasticity is equal to 0.51.

Furthermore and as a complement to the elasticities, Figure 2 shows both the NTM and TM cost curves in the agricultural sector based on the available data.[2] As shown, technical abatement costs in this sector are higher than the non-technical ones and the cost saving would not be considerable.

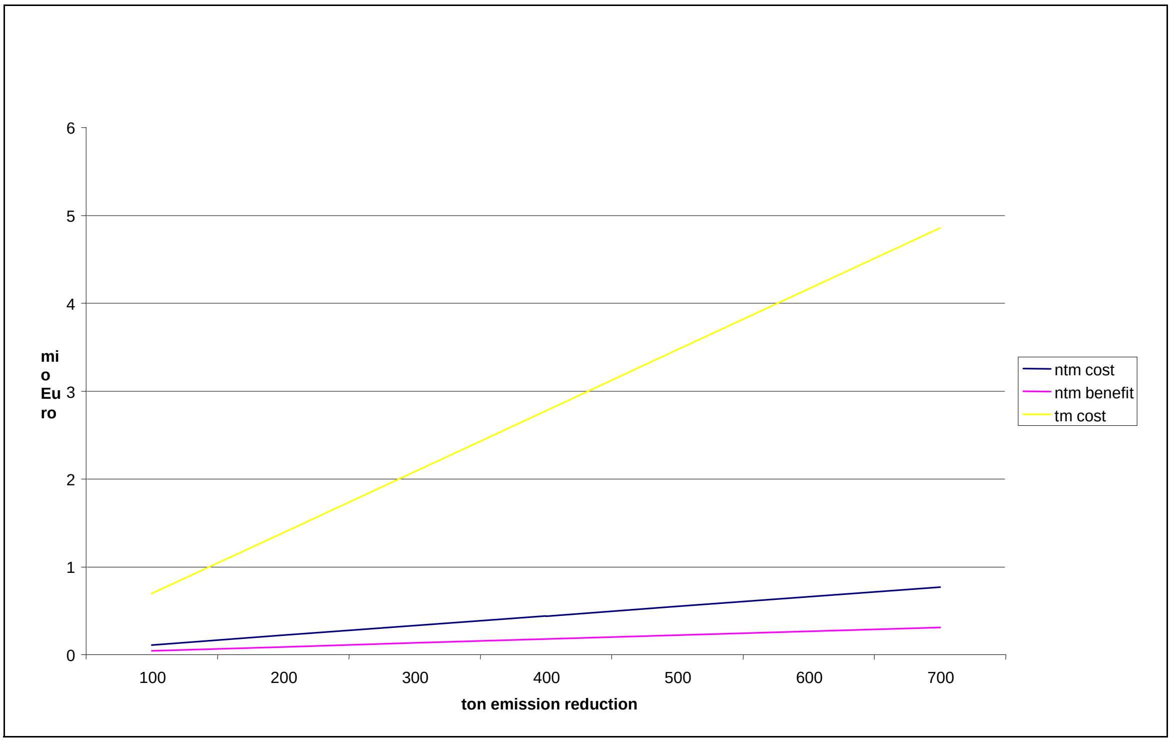


Figure 2 Cost curves in the agricultural sector

6.4 The energy sector

The environment in general and human health in particular has been damaged increasingly during the last decades depending on production and consumption of energy. Hence, the energy sector is agreed to be the main source of emissions of many noxious gases. The most important of these gases are the GHG as well as NOx and SO_2. Being aware of this fact, action programs have been started, legislation have been adopted and pricing policies have been imposed to limit and/or reduce the noxious emissions.

[2] In the process of running the regression of the cost curves the constant term is dropped.

6.4.1 Literature review

In the review of the use of NTM as well as the corresponding costs several studies and reports related mainly to Swedish conditions and a few studies based on US data have been studied. These studies are as follows:

-Cost-efficient reduction of sulphur- and nitrogen oxides (Westerlund, 2003). This thesis collects environmental impact reports to compile a database of boilers in the Swedish district heating system. With help of the database the study makes an inventory of the emissions from certain energy production processes in Sweden. It also conducts an economical analysis of selected measures that could be used to reduce emissions of sulphur- and nitrogen oxides.

-Evaluation of costs and reduction potentials for PM, sulphur- and nitrogen oxides for bio fuel- and oil burned heating plants (Montin, 2004). The results in this thesis are based on literature reviews, interviews and empirical studies. Similar to the study above this report compile a database of boilers from environmental impact reports to make an inventory of the emissions. An economical analysis is conducted to approximate the total costs of fuel substitution in all boilers in Sweden between 0 – 50 MW.

-Profitable ways to save energy (Skane Energy Agency, 2000). The measures in this documentation are basically for the service sector. A model of an office has been the key instrument to study efficient ways to save energy. Based on the energy saved and costs, the pay-off time is estimated for each measure.

-The energy and future in Norrbotten (Pettersson (ed), 2001). An overview of the energy status has been conducted in the county of Norrbotten. The chapter of current interest in this study, is based on literature studies concerning energy saving and has a couple of measures with costs and potential energy savings.

-Energy conservation within the industry sectors (the Swedish Energy Agency & Environmental Protection Agency, 2001). Case studies have been studied in this report to make the industry more aware of their energy consumption. The costs and reduction data used from this report comes from those measures that can be applied to several different industries.

-Save energy with efficient blenders (Swedish Energy Agency, 2003). This is a simple 2-page study that compares old tap water blenders with new energy efficient blenders. The result shows how much energy a smaller and a larger household would save if they install the new blenders considering the investment costs.

-Market failures and barriers as a basis for clean energy policies (Brown, 2001). This article examines why consumers on the U.S. market do not buy the available most energy efficient appliances, even though it is the less expensive. The paper provides an assessment of numerous measures with related cost savings.

-Electricity end-use efficiency: Experience with technologies, markets, and policies throughout the world (Levine et al., 1995). This paper describes small market failures, foremost in the U.S., that have limited the acceptance of energy efficient equipment. It also reviews some experiences with different policies to overcome these failures and promote end-use efficiency.

6.4.2 Data description

In the major part of the literature reviewed in this study, no reductions of emissions to air have been presented. Because of this all emissions are calculated backwards corresponding to the reduction of used energy. There are two kinds of energy that are taken into consideration. These are electricity and heat but other measures leading to emission reduction include fuel shifting. The data for NTM including annual costs/savings and emission reduction is shown in appendix IV. The data is based on the emissions factors for NOx, SO_2 and CO_2 for electricity, heat and fuel shifting. The allocation factors based on cost ratio for the pollutants are 0.39 for NOx, 0.59 for SO_2 and 0.02 for CO_2.

The NTM data is annualised assuming a real interest rate of 6 percent as well as a technical lifetime of 15 years. For TM the data is from IIASA's model RAINS (http://www.iiasa.ac.at/web-apps/tap/RainsWeb/).

Electricity

The marginal production for electricity in Sweden is coal burned power plants in Denmark (ECON, 2002). The emission factors coal power plants are shown in Table 4.

Table 4 Emission factors for coal burned power plant (Uppenberg et al, 1999).

Pollutant	**Emission factor (kg/prod. kWh)**
NO_x	0,000353
SO2	0,000576
CO_2	0,756

Heat

The production of heat varies a lot in Sweden as the heat is produced at a local level and not at a national level such as electricity. Therefore a heat-mix for Sweden was constructed. Table 5 shows the emissions factors of NO_X, SO_2 and CO_2 for heat production from district heating, electricity, oil and bio fuel.

Table 5 Emission factors for different types of heat production, (EK, 2003)

Pollutant	**Emission factors**			
	District heating (kg/prod. kWh)	Electricity (kg/prod. kWh)	Oil (kg/prod. kWh)	Bio fuel (kg/prod. kWh)
NO_x	0,00025	0,000353	0,000486	0,000328
SO_2	0,000325	0,000576	0,000756	0,000137
CO_2	0,0105	0,756	0,324	0,00432

Based on this data a national mean can be as shown in Table 6.

Table 6 Emission factors for heat production in Sweden

Pollutant	**Emission factor heat mix (kg/prod. kWh)**
NO_x	0,000340
SO_2	0,000498
CO_2	0,278

Characterisation with EPS2000

Different pollutants do not have the same impact on the environment and when they do it is very rarely to the same degree. In this study there are three pollutants with different impacts. Costs and savings in this study, are not pollutant specific as in the RAINS model, therefore an allocation must be done. To be able to allocate costs and savings to each pollutant the characterisation method called EPS2000 is used. This method is based on the willingness-to-pay for avoiding damages on environmental safeguard subjects.

6.4.3 Estimated results

Table 7 brings together the regression results where the dependant variable is abatement cost in the energy sector related to households, industry and the service sectors. The independent variable is emission reduction for NO_X. The ambitions to estimate the impacts of emission reduction of other pollutants showed to be quite difficult leading to multicolinearity depending on the use of EPS2000 as a weight method gave results that are basically simulated and thereby highly correlated. Further, to distinguish the effects of emission reductions on cost in different sectors i.e. household, industry and service, by way of dummy variables gave no significant results and the dummies have shown to be highly correlated with each other.

Table 7 Cost effective reduction of NO_X.

	NTM saving	TM cost
Variable	Estimate	Estimate
Emission reduction	0.98	0.96
	(29.56)*	(11.47)
Adj R^2	0.96	0.70
Number of observations	31	53

*The values within the brackets are the t-values.

As shown in the table an increase in emission reduction by one percent (other things being equal) would lead to a 0.98 percent of cost saving using NTM. This is almost a one to one relationship between cost saving and emission reduction of NOx. Further, the generated costs by NTM, would increase by 0.71 percent if emission reduction of NO_X is one percent. However, since the number of observations is limited i.e., 9 the results are not shown on the table.

Since the TM used in the analysis are the RAINS measures, which are cost effective, they are shown in this case to be better than the general cost of NTM used to reduce emissions of NO_X in the energy sector.

On the other hand if the dependent variable is emission reduction and the dependent is cost the elasticities are highly significant. For NTM saving they are estimated to be equal to 0.98. In the cases of NTM cost the elasticity is equal to 0.95. For the TM cost the estimated elasticity is equal to 0.73.

Such as in the case of the agricultural sector Figure 3 shows the cost curves for both NTM and TM in the energy sector. These curves are based on the available data in this sector.[3] Although the NTM cost saving curve is based on limited data it is shown here in order to give an idea on the shape of this curve.

[3] In the process of running the regression of the cost curves the constant term is dropped.

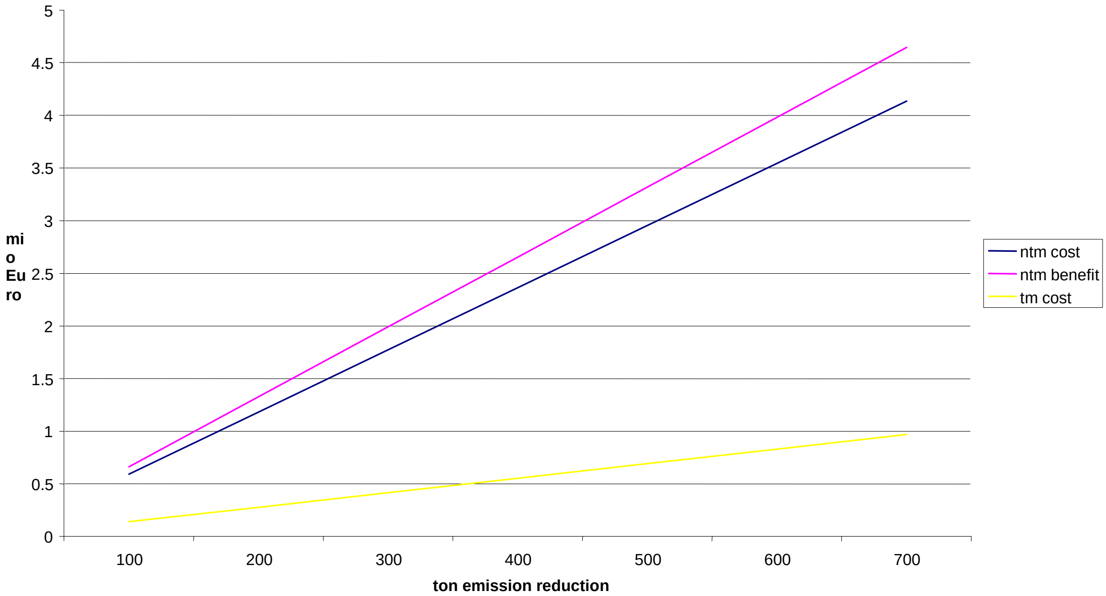


Figure 3 Cost curve the energy sector

As shown in the figure emission reductions being the result of TM would be more cost effective than in the case of NTM. However, NTM would lead to considerable cost saving if implemented in this sector.

6.5 The shipping sector

As mentioned earlier, the shipping sector is regarded as a sector where cost effective abatement measures are still available. These measures are, as for all sectors, both technical and non-technical in their nature. In general, one of the most discussed pollution sources is the sulphur content in bunker fuel.

6.5.1 Literature Review

A number of articles and reports discuss abatement measures in the shipping sector, but much of the discussion is held on a level that is too general to be suitable for a meta-analysis of measures. In many cases, taxes and harbour fees are listed, but with no reported effect on emission reductions. The IMO study on greenhouse gas emissions from ships (Henningsen, 2000) presents a number of 'operational measures' that could potentially be adopted on the international shipping sector. These 'operational measures' have the same general characteristics as the NTM as suggested in this report (chapter 3) and should be classified as efficiency NTM using the classification suggested in chapter 4. Of great importance to the shipping sector is also the fuel substitution measure to remove sulphur emissions. Three estimates are compared in this study, output from RAINS (http://www.iiasa.ac.at/web-apps/tap/RainsWeb/), Sabathier (2003) and Henningsen (2000). Furthermore, a few set of data from ENTEC (IIASA, 2005) have been used for comparison.

6.5.2 Data description

The identified data is not enough to enable a meta regression analysis. Instead, a descriptive analysis, including a comparison of different types of abatement measures, is carried out. The data from IMO is presented as percentage reduction in emission and percentage increase in initial and operating costs. Firstly, this data has to be converted into tons and Euro. This requires the use of a 'standard case' ship. This study uses the data for a container ship traversing the Atlantic Ocean between Gothenburg and Boston as the 'Standard case' (Flodström, 2005). This 'standard case' is used for calculations of emission reductions and their corresponding costs.

The selected cargo ship is a 109 000 ton dead weight tonnage ship that takes 121 hours to traverse the Atlantic Ocean. During that time it consumes 25 ton Marine Diesel Oil (MDO) and 1022 ton Heavy Fuel Oil (HFO) (Flodström, 2005). Ships of this size generally have an activity profile of 6000 hours per year (Henningsen, 2000). This results in annual fuel consumption of 1241 ton MDO and 50 695 ton HFO per year. This fuel data combined with emission data from CORINAIR enables calculations of emission reductions from reductions in fuel use. A reduction in fuel use also corresponds to a net-gain (negative cost) due to savings in fuel costs. No other costs are considered to be of any significant size for these fuel saving measures (Henningsen, 2000).

6.5.3 Description of the results

A summarising presentation is compelled in which some of the more frequently discussed measures are compared to the efficiency NTM in Henningsen (2000). Furthermore, fuel substitution measures are included as well, and different sources for cost calculations are presented. The efficiency NTM from Henningsen (2000) are considered as efficiency improvements, and the costs are calculated as fuel savings from the measure. The fuel substitution into low-sulphur fuels also results in some fuel savings since the high quality fuels also have better energy characteristics (Henningsen, 2000). The costs for implementation of technical measures are calculated by using the unit abatement costs. For example, the HAM measure has a unit abatement cost of € 272 per ton NO_x removed. The removal potential is 60% of the original emissions. Applying this to the standard case results in a removal of 2711 ton NO_x, with a cost of € 272 * 2711 ~ 737 000 € as shown in Table 8 below. The costs for the efficiency NTM are calculated from reduced fuel usage and fuel costs using data from Sabathier (2003).

Table 8 separates technical, fuel substitution and operational measures. The reason is that fuel substitution is treated separately later in this section; otherwise fuel substitution is generally regarded as a NTM, just like operational measures. A more complete description of the measures in the table is found in appendix VI.

Table 8 List of measures applied to the standard ship emissions

	Measure	Reduction			Savings	Cost	Source
		CO_2 [ton]	*SO_2 [ton]*	*NO_x [ton]*	*[€*10^6]*	*[€*10^6]*	
Technical measures	HAM			2711		0.74	Henningsen, 2000
	HAM			3163		0.86	IIASA, 2005
	SCR			4067		1.90	Henningsen, 2000
	SCR			4067		1.90	IIASA, 2005
Fuel substitution	Fuel Shift from 2.9% to 0.5% S		2433			3.40	Sabathier et al., 2003
	Fuel shift HFO-MDO	7232	1643	441		3.67	Henningsen, 2000
	Fuel shift to low sulphur fuel oil		307590			179.35	http://www.iiasa.ac.at/web-apps/tap/RainsWeb/
	Fuel shift to diesel oil <0.2% S		1070			1.87	-"-
	Fuel shift to diesel oil <0.045% S		550			2.89	-"-
Efficiency NTM	*Improved fleet planning*	*37044*	*619*	*1017*	*0.93*		Henningsen, 2000
	Hull design	20580			0.51		Henningsen, 2000
	Weather routing	4939	82	136	0.12		Henningsen, 2000
	Just in time' routing	4939	82	136	0.12		Henningsen, 2000
	Optimal cargo handling	4939	82	136	0.12		Henningsen, 2000
	Optimal Berth. Mooring anchor	2470	41	68	0.06		Henningsen, 2000
	Constant RPM*, propeller	1646	27	45	0.04		Henningsen, 2000
	Optimal propeller pitch	1646	27	45	0.04		Henningsen, 2000
	Minimum ballast	823	14	23	0.02		Henningsen, 2000
	Optimal trim	823	14	23	0.02		Henningsen, 2000
	Optimal rudder	247	4	7	0.01		Henningsen, 2000

*RPM = Rotations per Minute

The following tables separate the measures with respect to the emission reductions for each pollutant relevant to the measure. The unit abatement costs presented in Table 9, Table 10 and Table 11 are not weighted in any way. This implicates that the unit costs shown in the tables are fully allocated towards each pollutant in every table. A result from this is the extremely high unit cost for NO_x abatement by fuel shift, a measure not intended to remove any significant amount of NO_x emissions. There are weighting measures that could be used to harmonise these results, such as EPS 2000 discussed above. But in an effort to keep some sort of conformity with the results from the other sectors, weighting will be avoided in these results as well.

The measures are ordered with respect to their cost effectiveness. For example, the measure 'just in time routing' reduces emissions of CO_2 with 4939 tons and includes a cost saving of 0.12 million € with the following unit cost of –25 € / ton CO_2 abated. The tables for SO_2 and NO_x abatement are composed in the same manner. Furthermore, one of the most efficient measures in the shipping sector according to Henningsen (2000) is the 'Improved fleet planning', which is a measure that is more adapted to the entire fleet than to any specific ship. There is also a very large span between the minimum (5%) and maximum (40%) fuel savings that are available from this measure, which makes the effect from the measure even more uncertain. Therefore, the measure is written in *italic.*

Table 9 Unit abatement costs, CO_2

Measure	Reduction CO_2 [ton]	Savings [€*10^6]	Cost [€*10^6]	Unit costs [€ / ton]	Source
Improved fleet planning	37044	0.93		-25	Henningsen, 2000
Optimal cargo handling	4939	0.12		-25	Henningsen, 2000
Just in time' routing	4939	0.12		-25	Henningsen, 2000
Weather routing	4939	0.12		-25	Henningsen, 2000
Optimal Berth Mooring anchor	2470	0.06		-25	Henningsen, 2000
Constant RPM	1646	0.04		-25	Henningsen, 2000
Optimal prop pitch	1646	0.04		-25	Henningsen, 2000
Optimal trim	823	0.02		-25	Henningsen, 2000
Minimum ballast	823	0.02		-25	Henningsen, 2000
Optimal rudder	247	0.01		-25	Henningsen, 2000
Hull design	20580	0.51		-24.8	Henningsen, 2000
Fuel shift HFO-MDO	7232		3.67	508	Henningsen, 2000

In Table 10, which presents unit abatement costs for reduced sulphur emissions, the fuel shift costs from the RAINS model (http://www.iiasa.ac.at/web-apps/tap/RainsWeb/) are explained a bit further. These values regard a fuel shift in the entire Atlantic Ocean transport fleet, which explains the large numbers. In this table the focus should be on the unit abatement costs. It suggests that fuel shift is not cost effective compared to the operational measures.

Table 10 Unit abatement costs, SO_2

Measure	**Reduction SO_2[ton]**	**Savings [€*10^6]**	**Cost [€*10^6]**	**Unit cost [€ / ton]**	**Source**
Improved fleet planning	619	0.93		-1507	Henningsen, 2000
Optimal cargo handling	82	0.12		-1507	Henningsen, 2000
Just in time' routing	82	0.12		-1507	Henningsen, 2000
Weather routing	82	0.12		-1507	Henningsen, 2000
Opt. Berth. Mooring anchor	41	0.06		-1507	Henningsen, 2000
Optimal propeller pitch	27	0.04		-1507	Henningsen, 2000
Constant RPM	27	0.04		-1507	Henningsen, 2000
Minimum ballast	14	0.02		-1507	Henningsen, 2000
Optimal trim	14	0.02		-1507	Henningsen, 2000
Optimal rudder	4	0.01		-1507	Henningsen, 2000
Fuel shift from 2.9% to 0.5% S	2433		3.40	1398	Sabathier et al., 2003
Fuel shift HFO-MDO	2433		3.67	1510	Henningsen, 2000
Fuel shift to low sulphur fuel oil	307590		179.35	583	http://www.iiasa.ac.at/web-apps/tap/RainsWeb/
Fuel shift to diesel oil <0.2% S	1070		1.87	1748	-"-
Fuel shift to diesel oil <0.045% S	550		2.89	5255*	-"-

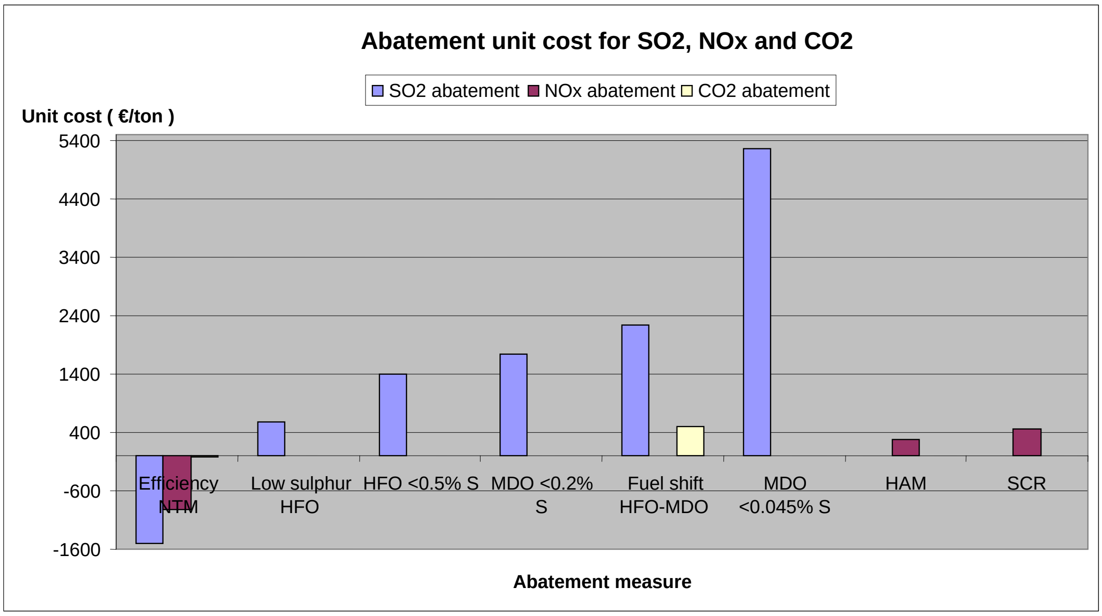
*5255 indicates the marginal cost for the measure; the unit cost is € 2939.

The main focus of NO_x abatement in the shipping sector is often on technology specifications. Techniques such as Humid Air Motors (HAM) and Selective Catalytic Removal (SCR) are often mentioned. These techniques are in the 'standard case' resulting in high reductions but with rather high unit costs.

Table 11 Unit abatement costs, NO_x

Measure	Reduction NO_x[ton]	Savings [€*10^6]	Cost [€*10^6]	Unit cost [€ / ton]	Source
Improved fleet planning	1017	0.93		-917	Henningsen, 2000
Optimal rudder	7	0.01		-917	Henningsen, 2000
Constant RPM	45	0.04		-917	Henningsen, 2000
Just in time' routing	136	0.12		-917	Henningsen, 2000
Minimum ballast	23	0.02		-917	Henningsen, 2000
Optimal trim	23	0.02		-917	Henningsen, 2000
Weather routing	136	0.12		-917	Henningsen, 2000
Opt. Berth. Mooring anchor	68	0.06		-917	Henningsen, 2000
Optimal cargo handling	136	0.12		-917	Henningsen, 2000
Optimal prop pitch	45	0.04		-917	Henningsen, 2000
HAM	3163		0.86	272	IIASA, 2005
SCR	4067		1.90	468	IIASA, 2005
Fuel shift HFO-MDO	*441*		*3.67*	*8329*	Henningsen, 2000

Figure 4 shows a summary for the examined measures comparing operational measures with fuel substitution measures and the technical measures HAM and SCR. This figure shows what has been previously indicated, namely that operational measures often is a very cost effective measure. However, fuel substitution costs show a very large variance, dependent on implementation rate and sulphur content in the desired fuel. It must be stressed that these numbers do not indicate the applicability and total removal potential of the measures in the shipping sector. This is rather a comparison of cost effectiveness.



* The NTM cost for CO_2 can not be seen in this staple diagram since the unit cost is very small compared to other measures (-25 € / ton).

Figure 4. Unit costs for SO2, NOx and CO2 abatement

Fuel substitution
The discussion of fuel substitution can somewhat be clarified by the comparison of different price levels for the different fuels as given in the literature. The main method used for calculation of fuel substitution costs is through the price difference between the high sulphur HFO and the low sulphur HFO or a MDO. The most thorough study on fuel substitution costs is in Sabathier (2003) where the costs for a full substitution to marine bunker fuel with sulphur content of less than 0,5% sulphur is calculated taking into account the required and available raw material for substitution. Sabathier (2003) combines the fuel price difference with costs for desulphurising bunker fuels in order to calculate costs dependent on required volumes. The effect on the cost effectiveness from varying relative prices is illustrated by the price differences given Henningsen (2000), Sabathier (2003) and www.bunkerworld.com (2005). With the current high fuel prices, the costs for fuel shift are much higher than in the given examples.

Henningsen (2000) indicates that the price difference between HFO and MDO usually lies between $ 80 – 100 / ton, Sabathier (2003) calculates the price premium for the shift from 2.9 % and 0.5 % marine bunkers to be between €$_{2002}$ 47 - 93 / ton. The lower estimate is based on the price difference between different types of bunker fuel, while the higher estimate is based on the cost for desulphurising fuels. The current prices (2005-11-04) on IFO 380 and MDO in Rotterdam serve as current price premium for fuel substitution between HFO and MDO (www.bunkerworld.com). See Table 12.

Table 12 Fuel prices in different studies and current situation

	Henningsen 2000	Sabathier 2003 (Average 1997-2001)	Bunkerworld.com
Fuel class	[$ / ton]	[$ / ton]	[$ / ton]
IFO 380	-	97	265
MDO	Price for IFO 380 + $ (80 – 100)	186	488.

Table 13 shows the importance of relative prices when estimating the costs for fuel shifts. The abatement cost would vary from 1439 to 3749 € / ton SO_2 dependent on which fuel prices that are used. In this table, the sulphur removal data from Henningsen (2000) is used.

Table 13 Potential abatement cost of fuel substitution using Henningsen (2000).

	Specifications	Abatement cost [€*10^6]	Reduction [ton SO2]	Unit cost* [€ / ton SO2]
Price difference 2005-11-04, IFO 380 and MDO (bunkerworld.com)	An 1.6 % reduction in S content (60% emission reduction)	9.12	2433	3749
Price difference 2003 (Sabathier)	An 1.6 % reduction in S content (60% emission reduction)	3.63	2433	1439
Price difference 2000 (Henningsen)	An 1.6 % reduction in S content (60% emission reduction)	3.67	2433	1510

*The unit cost is calculated by dividing the abatement cost with the removed emissions.

As a comparison, the shift from high- to low sulphur HFO, and a shift from HFO to MDO is summarised in the shipping abatement options presented in RAINS (http://www.iiasa.ac.at/web-apps/tap/RainsWeb/). These data are not applied to the standard case, but serves as an illustration of the fuel substitution abatement costs and potential in the Atlantic Ocean for the year 2000. See Table 14.

Table 14 Removal potential and costs for fuel substitution calculated in RAINS

Specifications	Abatement cost [€*10^6]	Reduction [ton SO2]	Marginal cost [€ / ton SO2]	Unit cost [€ / ton SO2]
HFO to LowS HFO	179.35	307590	583	583
HFO to MDO <0.2% S	1.87	1070	1748	1749
HFO to MDO <0.045% S	2.89	550	5255	2940

The tables above illustrate the importance of relative prices for cost effectiveness of the fuel substitution measure. Different relative prices cause the cost effectiveness for the measure to vary from € 1439 to € 3749 / ton sulphur removed. During some periods, the MDO fuel has been even cheaper than the HFO fuel (Henningsen, 2000), which would result in a net benefit from implementing the measure. This suggests that a static comparison of current or average prices, that do not take into account future changes in relative prices can cause the cost estimates to differ significantly from the actual emission reduction costs. By only using observed price differences between different fuel classes, the future cost effects resulting from increased demand and technical development can not be accounted for. Demand and technical development often explain parts of price changes, so an exclusion of these effects will alter the estimated cost effectiveness of the measure.

7 Removal potential and the relative importance of the measures in the studies

7.1 Introduction

The meta-analysis performed in this study is used to answer the question whether NTM as a category is more efficient than TM. It does not, however, give any indication on the total potential of NTM in relation to NTM. And although a meta-analysis can be used to show that NTM can be more cost effective than TM, this information needs to be complemented with estimations on the total effect on emissions from NTM. In this chapter, the total removal potential of NTM is briefly examined in order to determine its relative importance for emission abatement compared to TM. The total removal potential is examined sector by sector as analysed in the meta-analysis.

7.2 The agricultural sector

The measures indicated for the agricultural sector are sometimes repeated in different studies, and the removal potentials for the sector are therefore not suitable to add to each other. The removal potentials listed below are all related to either the national emissions of NH_3 or the agricultural emissions of NH_3 or even reduced leakage, dependent on which background material that is available. The potentials are therefore listed separately in Appendix V.

Table 15: Summary Ammonia, UK

Summary Cowell & ApSimon 1998		
Initial emissions 290 400 ton NH3-N		
	Removal potential (%)	Cost (million Euro)
TM removal	4.2	407.0
NTM removal	12.1	63.3

Table 16: Summary N leaching, Denmark

Summary Iversen, 1998		
Initial leaching was 230 000 tonnes N		
	Removal potential (%)	Cost (million Euro)
NTM removal:	15.1	131.6

Table 17: Summary ammonia, agriculture UK

Summary NARSES 2004		
Initial UK emissions were estimated as 272 000 ton NH3		
	Removal potential (%)	Cost (million Euro)
TM removal	5.0	193.7
NTM removal	1.3	14.3

The following table adapted from Bates 2001 shows an average reduction potential for the implementation of measures that reduces fertiliser use. These values are average values for all considered crops in the study by Bates 2001.

Table 18: Fertiliser use

Summary Bates 2001		
Average reduction in fertiliser use for different crops and measures.		
	Removal potential (%)	Cost (million Euro)
Spreader maintenance	10.1	-12.4
Fertiliser free zone	0.6	-0.4
Distribution geometry	5.4	-2.0
Precision farming	4.5	-39.7
Use Manure-N	5.6	-4.9

Table 19: RAINS measures, Ammonia

Summary RAINS:		
Initial emissions in Germany 2015: 611 950 ton NH3		
	Removal potential (%)	Cost (million Euro)
TM removal:	20.3	1284.7
NTM removal	7.7	40.76

Although the numbers shown in the tables above are rough estimates, these comparisons shows that for the agricultural sector, NTM are at the least significant, and in some studies even more efficient emission removal method than TM. The overall result from both the meta-analysis and the potential estimates shows that NTM has both high cost efficiency as a group compared to TM, and the potential of NTM is at least as high as for TM.

7.3 The energy sector

The emission baseline to which all studied measures are related is the emission data given by "Energy in Sweden: Facts and Figures 2004" (Swedish Energy Agency (STEM), 2004).

Table 20: Emission Estimates, Sweden

Swedish NO_x, SO_2 and CO_2 emissions	
National Emissions 2002 (kton)	
NOx	243
SO2	59
CO2	54800

For comparison, the abatement measures for Germany given in Web-RAINS are included, but for these the effect of these measures is related to the initial emissions according to the baseline scenario (CP_CLE) used in the RAINS calculations. Germany is kept as an illustrative example mainly since the comparison relates to percent change of emission, not total emissions.

Table 21: Emission Estimates, Germany

NO_x and SO_2 emissions in RAINS	
National emissions Germany 2000 (kton)	
NO_x	1645.4
SO_2	643.3

The measures indicated in the energy sector in this study are for three different types of sub-sectors; offices, industry and households. These all require different treatment when estimating their removal potential. For the NTM listed, some assumptions were made in order to estimate removal potential. The main assumption is that all measures can be fully implemented in the relevant sector. There are also some other simplifications in the emission reduction estimations. For the measures implemented in the office sub-sector, the main assumption is that an office space requires 160 kWh / m^2 and year for heat, and an additional 100 kWh / m^2 and year for electricity. The effect of the measures is calculated using an assumed office space of 2000 m^2 and a staff consisting of 150 persons. For the removal potential, data from Statistics Sweden (2005) was used. According to this source, the total office space in Sweden amounts to 34.6 million m^2 in 2004.

Other data used for the estimations of removal potential from the implementation of the measures are:

Table 22: Data used for estimation of abatement potentials

Other removal potentials in the energy sector			
Household energy, Swe	9.50E+13	Wh	Carlsson-Kanyama & Lindén 2002
Household electricity 2002, Swe	1.95E+13	Wh	(STEM, 2004)
Swedish private cars 2004	4 113 400		(www.scb.se as of 20060116)
Swedish Households 2002	4 701 315		(www.scb.se as of 20060116)
Office space:	3.46E+07	m2	(Statistics Sweden, 2005)
Swedish energy use	6.20E+14	Wh	(STEM, 2004)
Swedish houses	1 600 000		(STEM, 2003)
Swedish households 2002 with oil heating	400 000		(STEM, 2003)
Car engine heater usage ratio	0.5		(arbitrary)

The implementation potential for the measures adapted to households and offices is set as 0,5 in order to illustrate that the measures cannot be fully implemented. Partly since some measures might already be implemented, partly since a full implementation is difficult to achieve. The choice of the implementation ratio 0,5 is arbitrary and serves just as an illustration. Furthermore, some of the measures might be a bit overestimated, which would cause larger emission reductions than can be anticipated from an implementation of the measure. The chosen implementation ratios of the considered measures for the households are listed in table 4:

Table 23: Assumed implementation ratio of abatement measures, Household & Service

Measures and implementation ratios in offices and households		
Sub-sector	**Measure**	**Implementation ratio**
Office	Educate personnel	0.5
Office	Lower indoor temperature	0.5
Office	Low pressure fall filter	0.5
Office	Timer ventilation (12 h / day) – with heat recovery	0.5
Office	Timer ventilation (12 h / day) – without heat recovery	0.5
Office	Adjusted timer ventilation (6 h / day) – with heat recovery	0.5
Office	Adjusted timer ventilation (6 h / day) – without heat recovery	0.5
Office	Timer office equipment	0.5
Office	Telecontrol heating/electricity	0.5
Office	Multiple plugs with switch – computers	0.5
Office	Heating system calibration	0.5
Household	Timer, engine pre-heater	0.5
Household	Substitute blenders for tap water	0.5
Household	Substitute kitchen ware	0.5
Household	Change bath and showering habits – bath → shower	0.5
Household	Change bath and shower habits shower 15 min → 5 min	0.5
Household	Substitute fuel E01 → biofuel	0.5

Furthermore, for the energy sector, the measures listed are adopted on Swedish statistics on the number of companies in the related sectors. The estimations are based primarily on statistics regarding number of companies in the relevant sectors (workshop and Iron & steel) with more than 20 employees from Statistics Sweden. Statistic Sweden classifies companies in their SNI 2002 system. In this study the SNI-sectors considered are; In addition to this, an implementation rate is set (arbitrarily) to illustrate the uncertainties in the possibility to adopt the measure. The low implementation rate also illustrates the difficulties to adapt the aggregated data from Statistics Sweden into the measures used in the NTM study. So the resulting emission reductions can be regarded as low estimations of the effect of the measures.

According to these mentioned assumptions, the total energy use in Swedish offices is ~ 9 TWh per year (9 005 776 000 kWh). Which is a large number, considering the total Swedish energy use of ~ 620 TWh in 2002 (STEM 2004). Offices will constitute ~ 1.5% of the total energy use in Sweden if the assumptions are approximately correct. The emission reductions are calculated according to the energy mix that provides this energy use. The considered types of energy are electricity and heat.

Table 24: Used data and Assumed Implementation ratio, Industry

NTM in industrial parts of the energy sector, Sweden		
Non-technical measures	**No of companies**	**Implementation ratio**
Renovate vacuum pumps I&S	3	0.67
Regulation of process water (WS11)	3115	0.05
Regulation of process ventilation (WS)	3115	0.05
Bypass ability for ventilation (WS)	3115	0.05
Substitution of process ventilation (WS)	3115	0.05
Manual shutdown of ventilation during non-working hours (WS)	3115	0.05
Calibration of heating recycling compressed air tourniquets (WS)	3115	0.05
Substitute light fittings in workshop (WS)	3115	0.1
Substitute compressed air tourniquet (WS)	3115	0.05
Install telecontrol of electricity use on smelting ovens (Steel manufacturing)	8	0.1
Install timers in the ventilation system (WS)	3115	0.1

7.3.1 Resulting emission reduction in the Energy Sector

The results calculated from the data on measures and other relevant data for the industry, households and service sectors are presented in Table 27. For these calculations the emission factors in Table 25 have been used. Since emission reductions from energy savings can be calculated in different ways according to theoretical approach, a sensitivity analysis is performed and the results are shown in Table 28, Table 29 and Table 30. The results from the sensitivity analysis are calculated by using the emission factors shown in Table 26. Further discussion on the calculation on emission reduction from energy savings can be found in Appendix VII.

Table 25: Emission factors, core analysis

The emission factors used for the core analysis.			
	Electricity[1] (Danish coal)	**Heat[1] (Swedish mix)**	
NOx	3.53E-04	3.40E-04	kg/kWh
SO2	5.76E-04	4.98E-04	kg/kWh
CO2	7.56E-01	2.78E-01	kg/kWh

[1] Adapted from Lindström 2005/2006

Table 26: Emission factors, sensitivity analysis

Emission factors used for the sensitivity analysis.					
	Electricity[3] (50% nuclear / 50% hydro)	**Heat[2]**	**Hydro[3]**	**Gas condense [2]**	
NOx	2.30E-05	2.60E-04	1.15E-05	4.32E-04	Kg/kWh
SO2	5.03E-05	3.75E-04	1.03E-05	1.44E-06	Kg/kWh
CO2	8.37E-03	9.75E-02	3.76E-03	3.76E-01	Kg/kWh

[2] (Uppenberg et al., 1999)
[3] (Baumann & Tillman, 2004)

Table 27 shows the effects on emissions of NO_x, SO_2 and CO_2 from the implementation of the NTM in the energy sector considered in this study. As can be seen, the reduction in energy use is amplified in the reduction of pollutant emissions. STEM (2004) indicates that the energy use in the Swedish household and service sector constitutes 49 % (72.5 TWh) of the total energy use in Sweden (148.6 TWh) for the year 2002. The emission reductions for CO_2 are in all analyses very high for the household sector. In fact, the total emissions of CO_2 from the Swedish household and service sector are only 12.3 % (6760 kton) of the Swedish total emissions in 2002 (54753 kton) (STEM, 2004).

Table 27: Removal Potential, Core Analysis

Results from the core analysis, marginal production = coal power plants				
	Reduction in Swedish energy use (%)	**Swedish NO_x emission reduction (%)**	**Swedish SO_2 emission reduction (%)**	**Swedish CO_2 emission reduction (%)**
Office measures	0.30	0.27	1.73	1.69
Household measures	1.39	0.75	7.63	10.39
Industry measures	0.09	0.08	0.53	0.61
Power plant fuel shift	-	0.51	2.16	4.83
RAINS NOx measures	-	8.80	-	-
RAINS SO2 measures	-	-	23.01	-

In the sensitivity analyses, only the emission factors from the production of electricity and heat are varied. This implicates that the results from the power plant fuel shifts and the RAINS measures do not vary. In an effort to avoid more confusion than necessary, the values for power plant fuel shift and the RAINS measures are removed from the tables below. The effect of using gas condense instead of coal condense is clearly visible in the table below. The CO_2 emission reduction from the household sector changes from 10.39 % to 5.98 %.

Table 28: Removal Potential, Sensitivity Analysis 1

Result from the sensitivity analysis, marginal production = gas condense power plants				
	Reduction in Swedish energy use (%)	Swedish NO_x emission reduction (%)	Swedish SO_2 emission reduction (%)	Swedish CO_2 emission reduction (%)
Office measures	0.30	0.26	0.71	0.74
Household measures	1.39	0.74	2.67	5.98
Industry measures	0.09	0.09	0.14	0.28

As an illustrating example, the effect of using hydropower as marginal production of electricity will have an even larger impact on the emission reductions as compared to the core analysis.

Table 29: Removal Potential, Sensitivity Analysis 2

Result from the sensitivity analysis, marginal production = hydropower plants				
	Reduction in Swedish energy use (%)	Swedish NO_x emission reduction (%)	Swedish SO_2 emission reduction (%)	Swedish CO_2 emission reduction (%)
Office measures	0.30	0.12	0.72	0.20
Household measures	1.39	0.02	2.74	3.23
Industry measures	0.09	0.02	0.14	0.04

Finally, emissions resulting from calculations using average electricity production are presented in Table 30. One reason for doing this is that emission factors from average production can be suspected to suit better with the total emissions as given by STEM 2004. Furthermore, the reduction in Swedish energy use is almost 2 %, which makes the discussion on marginal or average production more relevant. Although it must be stressed that a reduction in energy consumption by 2 % should probably be considered as causing a marginal change in energy production (Ekvall, pers. comm., 2005)

Table 30: Removal Potential, Sensitivity Analysis 3

Result from the sensitivity analysis, average electricity production = hydro / nuclear				
	Reduction in Swedish energy use (%)	Swedish NO_x emission reduction (%)	Swedish SO_2 emission reduction (%)	Swedish CO_2 emission reduction (%)
Office measures	0.30	0.13	0.77	0.21
Household measures	1.39	0.04	3.02	3.27
Industry measures	0.09	0.03	0.17	0.04

8 Discussion

Definition

There is an absence of theoretical motivation of the different definitions and classification types in all the texts studied for this study. It might be that the classification in itself is irrelevant and just serves as an illustration. It could even be that the entire discussion on TM and NTM should be held on a more general level without requirements for definitions or classifications since the concepts could have very little practical implications in some cases. However, a suitable classification could potentially serve as a policy guideline to what type of NTM that can be considered as most cost effective and politically feasible. And commonly agreed definition could simplify future work with abatement measures and costs, possible even in integrating the results into IAM.

Within the name 'Non-technical measures' lies an underlying understanding on which measures that would be allowed to sort under these measures. The general idea could have been that NTM is supposed to be a group of measures summarising all the improvements in environmental performance that can be achieved without depending on technology specifications. The contrast is very clear to 'end-of-pipe' solutions and efficiency improving technologies that are both totally dependent on specific advances in the related technological field. If this is the original intent of the term NTM (or soft measures as some like to name them), then how did it go from a specification as to whether technology is used or not, to a distinction between emission factors or activity data?

The best example is to compare eco-driving with a new efficient engine, which reduces fuel consumption in the same amount. These two can be claimed to be TM if the functional unit on the activity data is [person-km] which is often the case in the available transport measures. But if the unit on the activity data would have been [energy demand], both measures would have been classified as NTM, following the activity data / emission factor approach presented earlier in the report.

There are two aspects that can be of importance for the discussion on NTM definitions. First is the consideration as to whether NTM could be defined as 'all measures but technical', just as the name suggest, and what would be the consequences of leaving the entire discussion on activity data / emission coefficients, supply- / demand measures, input / output changes behind? In models performed today, the calculations on emission reductions basically starts with the emissions given by the activity data and the unabated emission factor, followed by the reduction of the emission factor or the activity data by implementation of a measure. This shows that the terms used for describing measures are important for model calculations, which makes it hard to motivate a loose definition of NTM such as 'all measures but technical'. Secondly, could it be that the idea of NTM is based on the types of NTM that mainly considers conservation measures thus only affecting activity data? Examples of conservation measures can be shorter showers, using less detergent when washing clothes, putting the light out when leaving a room. All of which traditionally have been considered as environmentally friendly behaviour, and all of which could be classified as lowering levels of activity data (savings) in model calculations. Whether the NTM concept have the original purpose of mainly including these conservation measures is not possible to answer in this study, but it can at least be said that conservation measures have been considered as environmentally friendly behaviour for some time now. Furthermore, the definition could also be based on the practical limitations in IAM. As an example, changes in activity data as a mean to reduce emissions will be considered as abatement options, together with the traditional 'end-of-pipe' solutions. If these activity data changes were to be implemented in a 'pollutant abatement' cost curve together with measures that affect the emission factors, a difficult situation could occur. If the abatement effect from the measures affecting emission factors is based on the 'pre-measure' activity data, then these emission abatements will change in size if a measure is implemented that changes the activity data. So there would be some type of feedback mechanism affecting the emission reductions of previously implemented measures. This could in turn make cost effectiveness difficult to calculate and abatement cost curves difficult to derive.

These aspects all highlights the uncertainties and difficulties involved in the concept NTM. This contributes to the notion that maybe a common approach towards what is commonly known as NTM might not be a favourable treatment of the included abatement measures. It could be that the inclusion of the measures into IAM would be easier if another approach was used. This discussion is however completely outside the scope of this report.

Return to the previous discussion a bit. If we were to accept that a definition and a classification of NTM would contribute to the work with NTM in general and integration into IAM specifically, then the definition suggested in this report could potentially be useful since it is originated in the economic terms used in production processes. It could also be relatively easy to adopt to cost calculations. Furthermore, the classification approach could illustrate what types of NTM that has a positive net effect. For example, there exists some debate on the actual effect of efficiency improvements. Efficiency improvements can potentially cause economic savings for the polluter, which would enable the possibility for more polluting activities to take place.

The suggested definition in the report is mainly adapted to producers since it discusses input and output. But there is an intuitive problem with the translation of input/output into terms concerning the general public. A potential analogue to output for the producer could be utility for the consumer. As it is earlier described, most NTM are not supposed to directly alter the output of a producer. But the idea that NTM wouldn't change the utility for a consumer is not that easy to accept. For many of the discussed consumer-related NTM there is an evident case of experienced decreased utility. For example, changing from passenger cars to public transport can in many aspects be regarded as a reduction in 'life-quality'. But it can be claimed that the measure will keep the utility constant since the modal shift should result in additional disposable income (public transport are often cheaper than private cars) for the consumer. This extra disposable income could be used for other utility increasing purposes, leaving the consumer just as well of as before the modal shift. The discussion on whether the consumer measures should be extended into considering these types of aspects regarding utility or not is very interesting but too extensive for this report.

Top-down versus bottom-up

It seems like the classification of abatement measures in general as well as specific NTM classifications in the existing literature are classified with respect to the relevant policy area that would be involved if the measure would be implemented. The theoretical rationale for the different classifications is rarely presented, but it seems as if a 'top-down' approach is used in the some of the existing classifications. By changing from a 'top-down' to a 'bottom-up' approach the use of classification could be more relevant for the emission and cost calculations in the existing IAM, since these different classes represent three different ways to alter input to production. If one were to adapt the classification to a 'bottom-up' instead of a 'top-down' approach, the classification would be more adapted to modelling efforts. But there would probably be a trade-off with the translation to suitable policy instruments used to reach the desired effect.

Classification of NTM

The proposed definition of NTM, and the following distinction between NTM and TM is from a general approach with the intent to characterise a very large group of measures and sectors. The subsequent classification of NTM conditioned by this distinction shows however that for specific examples the distinction between TM and NTM is sometimes hard to verify. One possible explanation can be that the distinction regards the primary effect on emissions from the implementation of an NTM. There are often secondary effects that complicate the situation. What could be regarded as secondary effects can be caused by changes in relative prices due to the costly implementation of a measure, an effect that is disregarded in the suggested definition of NTM in the earlier chapters of this study. However, it is partly recognised in the discussion on NTM within the MERLIN project. If one were to use economic terms in this discussion, own-price effects or substitution effects could replace the term secondary effects. Another distorting aspect is whether effects of a measure are considered in the long- or short term. Short-term and long-term effects are to some extent considered in the TREMOVE model (de Ceuster, 2005). All these effects might cause the measures to look similar, but they could still originally be caused by efficiency improvements, substitution or demand changes. The problem with similarities between the different NTM classes as well as between TM and NTM can justify caution in the discussion on different classifications and definitions of abatement measures.

The cost of NTM

The inclusion of other costs than the financial costs for any measure might become more relevant when discussing NTM. Traditionally, the costs of a measure are often indicated by the investment costs, fixed operating costs and variable operating costs. All of these represent financial costs, and apart from these, no other costs are usually considered. As mentioned in chapter 5, transaction costs are mostly disregarded.

But if NTM is included in IAM, and it is suspected that a large part of the costs of an NTM might consist of transaction costs (measure implementation) as well as non-financial consumer costs, then the underestimation of implementation costs might lead to over-compliance. There is still a gap in knowledge about the transaction costs and non-financial costs of non-technical measures, so the discussion is so far kept on a general level. But if transaction costs and non-financial costs would constitute a large part of the implementation cost of NTM, further work should be required in order to find a suitable way to include these costs into a model, otherwise a sub-optimal implementation of the measure could be the result.

One possibility might be to add some kind of market based instrument model to RAINS, where the costs for the instruments are included. This would make it possible to include only the cost for NTM and TM in the RAINS model. As most instruments, to some extent, affect both TM and NTM this will also give more realistic cost estimates to the countries. Though, the connection between policy instruments and measures are not that clear and it will not be an easy task.

Meta-analysis

The results of the meta regression for the agricultural and the energy sector included in this study give some insight on the effectiveness of the NTM compared to TM. Depending on the nature of the subject i.e., a review of NTM the data has been very scarce to allow consistent and representative results for all European countries; Most of the NTM studied have only one study as origin. Further, the reviewed studies are often related to the emissions of different pollutants, which has led to the use of different conversion factors in order run the meta regression.

During the work with these meta-analyses, the intent has been to perform a further analysis on the different types of NTM. However, the limited data did not allow for a comparison for instance of the efficiency and substitution.

Furthermore, the independent variables in the agricultural and the energy sectors are nitrogen and NOx emission reduction, respectively. The ambitions to estimate the impacts of emission reduction of other pollutants showed to be quite difficult leading to multicolinearity depending on the use of for instance EPS2000 as a weight method. Using this method gave results that are basically simulated and thereby highly correlated. Further, in the energy sector, the distinction of the effects of emission reductions on cost in different sectors i.e. household, industry and service, by way of dummy variables gave no significant results and the dummies have shown to be highly correlated with each other.

Further work

The need for more knowledge in the field of NTM is important. There is strong evidence that traditionally used control measures for air pollutants are getting exhausted, when considering the substantial costs associated with these measures. This has been shown in reports prepared by the CAFE programme (http://europa.eu.int/comm/environment/air/cafe/). So highlighting less expensive measures is of outmost interest from a policy perspective.

In order to introduce these new measures in models and assessment tools, many methodological issues need to be addressed. The methods used to put a price tag and quantified emission reduction effects of NTM still require further attention. There is also a great need to collect and analyse data and examples on NTM from various countries in order to derive empirical relationships and to compare cost-efficiencies of these measures.

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Appendix I. NTM classification in the public sector

This study's theoretical diversification between TM and NTM described in chapter 3 of this study separates the two groups of measures in accordance with their effect on input and output of production. Within the NTM group, three abatement effects overall cause a reduction of emissions; substitution of inputs, efficiency improvements in input use, and reduced demand of output. The following discussion discusses NTM in the public sector. Societal non-technical measures can be directed both towards changes in consumption as well as other types of behavioural changes, which motivates these measures to regard the general public, not only consumers. However, the structural differences between TM and NTM as well as between the different classes of NTM can be regarded as similar regardless of whether the measures are directed towards production or the general public. But the input/output terminology shouldn't be used in both situations. Furthermore, in the following discussion on different types of NTM the reader must keep in mind that the technical or non-technical nature of any measure best can be recognised before the consequences of implementation costs of the measure are considered.

NTM for the public in general, a possible approach?

For NTM in the public sector the terms 'consumption goods' and 'society functions' are used, as the approximate equivalents to 'input' in production. Utility is considered as a corresponding equivalent to 'output' in production. There are a number of consumption goods and society functions that provide a certain utility for the public. These goods and functions can, for instance, consist of leisure time, food, house heating services, roads etc. The utilisation of these goods and/or functions represents a certain utility for the consumer.

As for production, the types of NTM considered for the general public is efficiency improvements, substitution and demand effects. Efficiency improvements implicate that any 'consumption good'/'society function' is used more efficiently/optimal in order to reduce emissions without necessarily reducing utility. An example of this would be a better planning for the use of personal car so that a maximum amount of services are provided with a minimum amount of driven kilometres. Substitution measures will change the mix of 'consumption good'/'society functions'. A transport modal shift represents for example a change in the mix of leisure time, public transport and private transport. As is the case with production, the demand measures do affect the utility of the consumer with a following change in utilisation of consumption goods or societal functions.

Appendix II. Classification of measures based on the work from the workshop on NTM 2006

Table 31 The measures studied in the agriculture sector classified in accordance to the recommendation from the workshop on NTM (Sternhufvud & Åström, 2006).

Technology	'end of pipe'	Low-tech covering for slurry tanks - pigs	Cowell, Apsimon 1998. Model Maraccas
		Scraper/sprinkler systems - cattle	Cowell, Apsimon 1998. Model Maraccas
		Covered tanks for all slurry storage - cattle	Cowell, Apsimon 1998. Model Maraccas
		Covered tanks for all slurry storage - dairy	Cowell, Apsimon 1998. Model Maraccas
		Slurry aeration and flushing systems - pigs	Cowell, Apsimon 1998. Model Maraccas
		Under-floor drying systems - poultry	Cowell, Apsimon 1998. Model Maraccas
		covering stored layer manure	Webb et al 2005
		covering stored broiler manure	Webb et al 2005
		Reducing the slatted area in pig buildings	Webb et al 2005
		Litter drying systems for broiler houses	Webb et al 2005
		Cover stored pig FYM	Webb et al 2005
		Cover stored beef FYM	Webb et al 2005
		DL-AGR_COWS-CS_LNA	www.iiasa.ac.at
		OL-AGR_BEEF-CS_high	www.iiasa.ac.at
		OL-AGR_BEEF-CS_LNA	www.iiasa.ac.at
		DL-AGR_COWS-SA_LNA	www.iiasa.ac.at
		NOF-FERTPRO-STRIP	www.iiasa.ac.at
		PS-AGR_PIG-BF_LNA_high	www.iiasa.ac.at
		PS-AGR_PIG-LNF_BF_LNA_high	www.iiasa.ac.at
		OL-AGR_BEEF-SA_LNA	www.iiasa.ac.at
	fuel quality	Natural crust formation of slurry lagoons - dairy	Cowell, Apsimon 1998. Model Maraccas
		Natural crust formation on slurry lagoons - cattle	Cowell, Apsimon 1998. Model Maraccas
		Natural crust formation on slurry tanks - dairy	Cowell, Apsimon 1998. Model Maraccas
		Crust formation on dairy slurry lagoons	Webb et al 2005
	conversion efficiency	Low-efficiency slurry application - cattle	Cowell, Apsimon 1998. Model Maraccas
		Low-efficiency slurry application - dairy	Cowell, Apsimon 1998. Model Maraccas
		Low-efficiency slurry application - pigs	Cowell, Apsimon 1998. Model Maraccas
		High-efficiency slurry application - cattle	Cowell, Apsimon 1998. Model Maraccas
		High-efficiency slurry application - dairy	Cowell, Apsimon 1998. Model Maraccas
		Mid-efficiency slurry application - dairy	Cowell, Apsimon 1998. Model Maraccas
		Mid-efficiency slurry application - cattle	Cowell, Apsimon 1998. Model Maraccas
		OP-AGR_POULT-LNA_high	www.iiasa.ac.at
		LH-AGR_POULT-LNA_high	www.iiasa.ac.at
		DL-AGR_COWS-LNA_high	www.iiasa.ac.at
		SH-AGR_OTANI-LNA_high	www.iiasa.ac.at
		PL-AGR_PIG-LNA_high	www.iiasa.ac.at

Technology	'end of pipe'	Low-tech covering for slurry tanks - pigs	Cowell, Apsimon 1998. Model Maraccas
		DS-AGR_COWS-LNA_high	www.iiasa.ac.at
		PS-AGR_PIG-LNA_high	www.iiasa.ac.at
		OL-AGR_BEEF-LNA_high	www.iiasa.ac.at
		OS-AGR_BEEF-LNA_high	www.iiasa.ac.at
		PS-AGR_PIG-LNF_LNA_high	www.iiasa.ac.at
	conversion technology	Conversion to stilt housing - poultry	Cowell, Apsimon 1998. Model Maraccas
		Nipple-drinking systems - poultry	Cowell, Apsimon 1998. Model Maraccas
	demand		
Miscellaneous e	land use planning	Groundwater protection areas	Iversen 1998
		Wetland restoration	Iversen 1998
		Afforestation	Iversen 1998
	time of use planning	Immediate ploughing solid waste - sheep & goat	Cowell, Apsimon 1998. Model Maraccas
		Immediate ploughing solid waste - cattle	Cowell, Apsimon 1998. Model Maraccas
		Imm. Ploughing of solid waste - dairy	Cowell, Apsimon 1998. Model Maraccas
		Immediate ploughing of slurry - cattle	Cowell, Apsimon 1998. Model Maraccas
		Immediate ploughing of solid waste - poultry	Cowell, Apsimon 1998. Model Maraccas
		Immediate ploughing of solid waste - pigs	Cowell, Apsimon 1998. Model Maraccas
		Immediate incorporation of pig slurry to arable land by disc	Webb et al 2005
		Imm incorp layer manure by disc	NARSES 2004
		Imm incorp Broiler type manure by disc	NARSES 2004
		Imm incorp Dairy cattle slurries by disc	NARSES 2004
		Imm incorp beef cattle slurries by disc	NARSES 2004
		Imm incorp PIG FYM by disc	NARSES 2004
		Imm incorp Beef cattle FYM by disc	NARSES 2004
		Imm incorp Dairy cattle FYM by disc	NARSES 2004
	Enforcement	Tightened requirement to utilise nitrogen in animal manure	Iversen 1998
		10% reduction in nitrogen standards for crops	Iversen 1998
		Tightened livestock density requirements	Iversen 1998
	Monitoring	Winter Wheat - precision farming	Bates 2001
		Spring Barley - precision farming	Bates 2001
		Grain Maize - precision farming	Bates 2001
Behavioural	demand / consumption	Grass - Fertiliser free zone	Bates 2001
		Catch crops	Iversen 1998
	substitution	Urea Substition - fertiliser	Cowell, Apsimon 1998. Model Maraccas
		Organic farming	Iversen 1998
		Wheat - Use Manure N	Bates 2001
		Potato - Use Manure N	Bates 2001
		NOF-FCON_UREA-SUB	www.iiasa.ac.at
	technology of choice		
	technology use	Grass - Spreader Maintenance	Bates 2001
		Maize - Spreader Maintenance	Bates 2001
		Potato - Spreader Maintenance	Bates 2001
		Sugar beet - Spreader Maintenance	Bates 2001
		Wheat - Spreader Maintenance	Bates 2001

Technology	'end of pipe'	Low-tech covering for slurry tanks - pigs	Cowell, Apsimon 1998. Model Maraccas
		Barley - Spreader Maintenance	Bates 2001
		Grass - Distribution Geometr	Bates 2001
		Maize - Distribution Geometr	Bates 2001
		Potato - Distribution Geometr	Bates 2001
		Sugar beet - Distribution Geometr	Bates 2001
		Wheat - Distribution Geometr	Bates 2001
		Barley - Distribution Geometr	Bates 2001

Table 32 The measures studied in the energy sector classified in accordance to the recommendation from the workshop on NTM (Sternhufvud & Åström, 2006).

Technology	'end of pipe'	
	fuel quality	Substitute E05 --> biofuel 0-10 MW Swe
		Substitute E05 --> biofuel 10-50 MW Swe
		Substitute E05 --> E01 10-50 MW Swe
		Substitute E05 --> E01 50-100 MW Swe
		Substitute E05 --> tall oil 10-50 MW Swe
		Substitute E05 --> tall oil 50-100 MW Swe
		Substitute E05 --> wood-powder 10-50 MW Swe
		Substitute E05 --> wood-powder 50-100 MW Swe
		Substitute E01 --> tall oil 10-50 MW Swe
		Substitute E01 --> tall oil 50-100 MW Swe
		Substitute E01 --> wood-powder 10-50 MW Swe
		Substitute E01 --> wood-powder 50-100 MW Swe
		Substitute tall oil --> wood-powder 10-50 MW Swe
		Substitute tall oil --> wood-powder 50-100 MW Swe
		S.B.H. E01 --> biofuel/one dwelling house Swe
	conversion efficiency	
	conversion technology	Flame retention head oil burner U.S.
	demand	Low Pressure Filter/(m3/s) Swe
		Timer Ventilation[4]/(m3/s) Swe
		Timer Ventilation[5] /(m3/s) Swe
		Adjust Timer Vent.[6]/(m3/s) Swe
		Adjust Timer Vent.[7]/(m3/s) Swe
		Timer Office Equipment Swe
		Timer Engine Pre-heater/jack Swe
		Telecontrol Heat/Electricity Swe
		Multiple Plug w. switch Cpu Swe
		Bypass ability for ventilation Swe
		Install telecontrol of electricity use on smelting ovens Swe
		Install timers in the ventilation system Swe
		Electronic ballast U.S.
		Automatic termination of clothes dryer U.S.
Miscellaneouse	land use planning	
	time of use planning	
	Enforcement	
	Monitoring	
Behavioural	demand / consumption	Educate Personnel, Swe
		Lower Indoor Temp./°C (office) Swe

[4] with heating recycling
[5] without heating recycling
[6] with heating recycling
[7] without heating recycling

Technology	'end of pipe'	
		Bath&shower;change habits Swe
		Shower;reduce shower time Swe
		Building design software U.S.
		Manual shutdown of ventilation during non-working hours Swe
	substitution	
	technology of choice	Substitute blenders for tap water Swe
		Substitute Kitchen Wares/household Swe
		Substitute compressed air tourniquet Swe
		Substitute light fittings in workshop Swe
		Substitution of process ventilation Swe
		Substituting heat pump U.S.
		Refrigerator compressor U.S.
		Low-emissive windows U.S.
		Substitute refrigerator U.S.
	technology use	Heating System Cal./°C Swe
		Regulation of process water Swe
		Regulation of process ventilation Swe
		Calibration of heating recycling compressed air tourniquets Swe
		Renovate vacuum pumps Swe

*EO5 = Swedish fuel oil, class 5, **EO1 = Swedish fuel oil, class 1

Appendix III. Cost effectiveness, economic efficiency and policy instruments

Cost effectiveness and economic efficiency

For cost effectiveness in the process of production (or consumption), it is argued that all environmental costs (or some of them) have in principle to be considered and internalised in the product price in order to give products their real cost. The concerned costs are the external costs where the process of internalisation of these costs is in accordance with the polluters pays principle (PPP) which has been adopted by OECD in 1972. The PPP is nowadays a cornerstone of both OECD and EU environmental policy. The OECD Council decision states:

The principle to be used for allocating costs of pollution prevention and control measures to encourage rational use of scarce environmental resources and to avoid distortions in international trade and investment is the so-called "Polluter-Pays Principle". The principle means that the polluter should bear the expenses of carrying out the above mentioned measures decided by public authorities to ensure that the environment is in an acceptable state...

Hence, the PPP as its name implies, makes polluters pay the cost to prevent pollution before it occurs i.e., PPP states that polluters must bear full financial responsibilities for pollution reduction. The PPP also supports the User Pays Principle as well as the Precautionary Principle, which demands that an activity or substance carrying a significant risk of environmental damage should be generally avoided.[8] When the PPP is applied, the price system is impacted, and a new price system that includes environmental costs is established. This idea is basically the same as that of the Pigovian tax. That is, the idea of internalising the external diseconomy.

In general, the analysis of environmental costs can be represented in terms of 2 figures. In figure 1 the optimal level of production of a good is q* and the optimal price is p*. Based on the existence of externalities the supply curve is equal to the marginal social curve (*MSC*) and the market demand curve represents the marginal social benefit (*MSB*) of the produced good. The *MSC* in turn is the sum of marginal private cost (*MPC*) and marginal damage cost (*MDC)* where this later is representing the negative externality caused by producing the good. Hence;

$$MSC = MPC + MDC$$

The intersection of *MSC* and *MSB* decides the optimal production level q^* and the optimal market equilibrium price p* and the level of damage cost is equal to $p0 - p^*$ leading to a reduction of the consumer surplus. The reduction level of the consumer surplus is of course depending on the elasticities of both the demand and supply of the product in question. For example, the more elastic the demand, the more production quantity changes and the fewer market prices change. In this case, it is difficult to shift the cost and companies have to bear higher cost. In the case of less elastic demand, the less production quantity changes and the more the market price changes. In this case, it is easy to shift the cost so that consumer bears more cost. On the other hand, if the supply curve is elastic the change in market price leads to higher change in supply and vice versa.

[8] The User Pays Principle is a variation of the polluter-pays principle. It calls upon the user of a natural resource to bear the cost of running down natural capital.

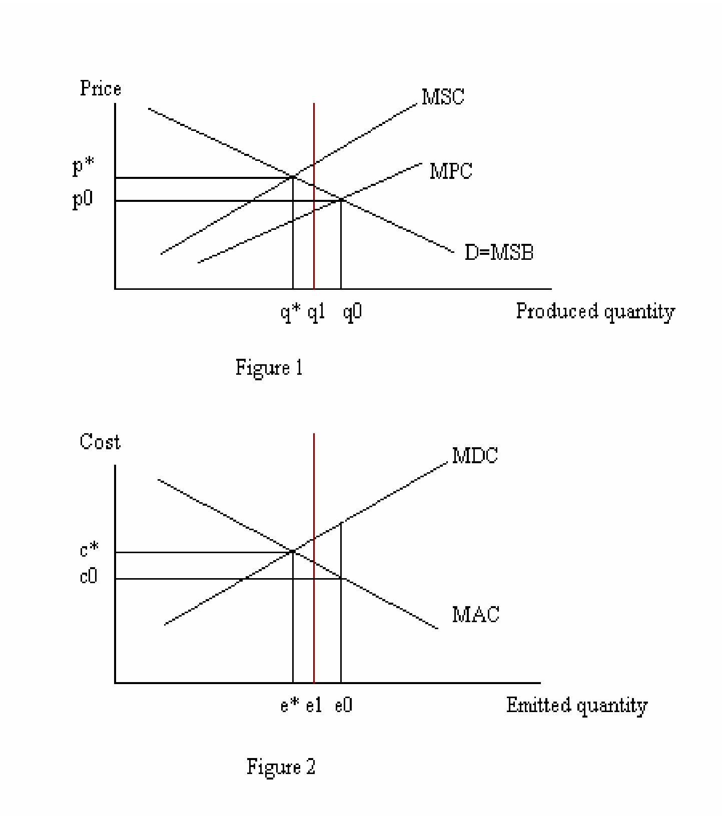

Figure 5 Optimal pollution level

In Figure the optimal pollution level corresponds to the intersection point e* of the marginal damage cost (MDC) and marginal abatement cost (MAC).

If MSC = MSB and MAC = MDC both cost effectiveness and economic efficiency are fulfilled and the polluters do bear the cost of preventing (or generating) the externality.

In the case where negative externalities are completely ignored, the production level would be q_0 and emissions level would be e_0 and the product price would be p_0. Hence, this market is not efficient. Nonetheless, although externalities may exist in a market, the measures used may be cost effective but they are not efficient such as in the case of producing the quantity q_1 and a corresponding price between p* and p_0. In this case cost effectiveness has been used as a method for finding the lowest cost of accomplishing an objective e.g. a standard (e_1 in figure 2) that may be based on economical or political reasons. The political reasons may be several and include politically decided levels or simply on the lack of knowledge of the damage costs etc. The economical reasons at the firm level may be that the abatement costs including technical measures are too high and may imply higher risk for the firm to be less competitive. Therefore the use of NTM may be a solution leading to both economic efficiency and thereby to cost effectiveness, if optimal environmental instruments are applied and all costs are known. Cost effectiveness analysis frequently involves an optimisation procedure. An optimisation procedure, in this context, is merely a systematic method for finding the lowest-cost means of accomplishing the objective e.g. e_1 in figure 2. This product does not produce an efficient allocation because the predetermined objective e_1 is not being efficient.

Policy instruments

In general, the environmental instruments used by government can be categorised into: regulatory, incentive based, informational, voluntary, and co-operative instruments. In this paper we will restrict the discussion to the first three ones.

1. The regulatory instruments refer often to the Command and Control Approach (CAC). The CAC policy uses regulations as instruments, fixing environmental standards to polluters. Polluters' compliance is based on monitoring and enforcement. Four types of standards can be considered: ambient quality standards, emission or discharge standards, process standards and product standards. Traditionally, CAC policies are regarded as being effective, easy to manage, relatively simple to impose and broadly accepted. However, from a welfare economic point of view they are inefficient because the policy goal will not be obtained at minimum cost for society. Also, emission standards do not provide an incentive to reduce emissions below the levels fixed by law nor do they require the polluter to pay for residual pollution.

2. The incentive-based instruments are based on the market approach (M). The M instruments are based on economic incentives which "provide market signals in the form of a modification of relative prices (taxation on certain products and/or a financial transfer (payment of a charge)". Seven types of economic incentives can be distinguished: emission charges or taxes, user charges, product charges or taxes, administrative charges or fees, marketable (tradable) permits, deposit-refund systems and subsidies. When M instruments are concerned, they have, in theory, all the efficiency properties of competitive market pricing. They trigger actions both among producers and consumers that allow the achievement of given environmental objectives at the lowest costs. The efficient nature of M instruments is due to the flexibility given to the polluters for devising a cost effective compliance strategy. Additional advantages of M instruments are their capacity to integrate environmental concerns with sectoral policy goals and to promote a gradual shift in the allocation of a society's resources required for sustainable development (http://www.rec.org). However, M instruments are often used in conjunction with CAC and information instruments since effective use of M instruments requires administrative and enforcement ability as well as effective information.

3. The information instruments (I). When it comes to informational instruments a distinction is usually made between information strategies for production and information strategies for consumption. Examples of information based strategies that may be introduced by government towards a cleaner production include (UNEP, 2005).

   -Promoting the adoption of targeted, high-profile demonstration projects, to demonstrate the techniques and cost-saving opportunities associated with cleaner production;
   -Encouraging educational institutions to incorporate preventative environmental management within their curricula, particularly within engineering and business courses;
   -Issuing high profile awards for enterprises that have effectively implemented cleaner production.

Since it is often difficult or even impossible for consumers to trace the original causes of environmental problems, it is vital that the authorities also use information instruments to improve the consumers understanding and awareness of these issues. Extensive research and monitoring work must be supported and publicised, and public awareness of environmental issues should be increased through education and special training. Other informative measures such as environmental labelling schemes attempt to control consumption patterns by encouraging consumers to use products and services that are less harmful to the environment (www.environment.fi).

Economic efficiency and policy instruments

When it comes to economic efficiency, it is often not easy to analyse this aspect with regard to environmental costs or the environmental instruments. Intuitively, one may argue on the fact that abatement costs may be reduced by the use of NTM leading thereby to economic efficiency and cost effectiveness. However, based on the last column of Table 33, efficiency is realised when environmental targets are reached subject to the fact that these targets are sustainable. This is not often the case because the evaluation of economic efficiency may depend on several reasons:

One reason refers to the fact that it is not possible to know with great precision what would have happened if a different environmental instrument had been chosen or if no regulation had been implemented at all.

The other reason is the uncertainty related to the evaluation of many of the environmental costs. Abatement costs are uncertain based on asymmetric information. Damage costs or external costs are uncertain based on the difficulties to evaluate the damages on the environment and the general public. Furthermore, the damage cost may be based on the standard price approach where abatement costs are used as a proxy variable for the damage cost.

The third reason concerns what costs should be included and what should be the costs to consider while evaluating economic efficiency. This is due to examples (that may concern both point and non-point polluters) such as:

- When evaluating the economic efficiency of policies to reduce non-point source pollution, administrative or transaction costs are usually not taken into account;
- When it comes to motorists such as in the absence of a correct price signal for using the roads and the atmosphere, car drivers need not pay either for the congestion costs that they inflict upon other road users or the pollution, which their journeys create. Any policy to tackle these problems must involve confronting motorists with the true costs of their journeys. Higher taxes would close the gap between private costs and social costs;
- Maddison et al. (1996), some of the UK's foremost environmental economists, suggested that the marginal external costs of transport in the UK "outweigh the taxes paid by road transport by a factor of three." They estimated that, at 1993 prices, road taxes covered only 31-36% of marginal external cost. They calculated the aggregate marginal external costs of UK road transport as between £45.9 and £52.9 billion, made up of on congestion costs £19.1 billion (36-42%), air pollution £19.7 billion (37-42%), noise pollution £2.6-3.1 billion 0.06%), road damage £1.5 billion (0.03%), accidents £2.9-9.4 billion (0.6-18%) and climate change £0.1 billion. (0.0002%).

Table 33 Key characteristics of environmental instruments

	Instruments	Producer pays	Consumer pays	Government receives	Government pays	Certainty of reaching environment targets
Emission limit	CAC	Abatement cost (TM, NTM)	Abatement cost (TM, NTM)	Nothing	Administrative cost	High
BAT	CAC	Abatement cost (TM, NTM)	Abatement cost (TM, NTM)	Nothing	Administrative cost	Depends on type of BAT
Tax	M	Abatement cost + cost of residual damage	Abatement cost + cost of residual damage	Cost of residual damage	Administrative cost	Low
Tradable permits auctioned by government	M	Abatement cost + auction price	-	Proceeds of auction	Administrative cost	High
Tradable permits given free	M	Abatement cost + transaction cost	-	nothing	Administrative cost	High
Information	CAC, M, I	Nothing	Nothing	Nothing	Administrative cost	Depends

Source: Adapted from http://www.arirabl.com/PAPERS/PollutionTax-PollAtmos.pdf.

Table 33 shows the different costs, except damage cost. All these costs might be estimated in the case of producers and consumers. In the case of the government, it both pays and receives while introducing policy instruments and the question is whether what government pays is less than what it receives. In order to answer this question a societal costs and benefits analysis of the instruments is the best method of evaluation.

On the other hand, such in the case of residual damage, the revenues to the government can in general be used for environmental funds that finance specific environmental projects and investments. But they do not have to. They can also be used for general public budgets or to cut budget deficits. Through eco-tax reform, governments can choose to shift taxation away from economic "goods" to environmental "bads". For example, income or sales taxes reduce the incentive for good things, such as work and consumption, which in turn hurts the economy.

Appendix IV. Non-technical measures in the energy sector

Non-technical measures	Reduction of NO_x (kg)	Reduction of SO_2 (kg)	Reduction of CO_2 (kg)	Total annualized cost(+)/savings(-) (Euro2000)
Educate Personnel Swe	30,3	46,2	38786	13735
Lower Indoor Temp./°C (office) Swe	5,1	7,5	4165	-952
Low Pressure Filter/(m3/s) Swe	0,7	1,2	1512	-89
Timer Ventilation[9]/(m3/s) Swe	10,0	15,9	18381	-1304
Timer Ventilation[10] /(m3/s) Swe	18,9	29,0	25679	-3005
Adjust Timer Vent.[11]/(m3/s) Swe	5,0	7,9	9190	-681
Adjust Timer Vent.[12]/(m3/s) Swe	9,4	14,5	12839	-1531
Timer Office Equipment Swe	0,7	1,2	1512	-85
Timer Engine Pre-heater/jack Swe	0,2	0,3	454	-17
Telecontrol Heat/Electricity Swe	17,2	26,5	23451	-2061
Multiple Plug w. switch Cpu Swe	2,6	4,3	5670	-44
Heating System Cal./°C Swe	5,1	7,5	4165	-199
Substitute blenders for tap water/household Swe	0,5	0,7	417	-10
Substitute Kitchen Wares/household Swe	0,5	0,9	1134	358
Bath&shower;change habits/household Swe	0,1	0,1	51	-12
Shower;reduce shower time/household Swe	0,4	0,6	333	-78
Renovate vacuum pumps Swe	2822,4	4608,0	6048000	-327184
Regulation of process water Swe	88,2	144,0	189000	-9971
Regulation of process ventilation Swe	98,8	161,3	211680	-10728
Bypass ability for ventilation Swe	97,0	158,4	207900	-10312
Substitution of process ventilation Swe	113,1	170,7	129902	-18009
Manual shutdown of ventilation during non-working hours Swe	113,8	174,5	153818	-18734
Calibration of heating recycling compressed air tourniquets Swe	196,9	289,0	161060	-36583
Substitute light fittings in workshop Swe	111,1	181,4	238140	5271
Substitute compressed air tourniquet Swe	63,5	103,7	136080	-3382

9 with heating recycling
10 without heating recycling
11 with heating recycling
12 without heating recycling

Install telecontrol of electricity use on smelting ovens Swe	2781,5	4541,2	5960304	-348645
Install timers in the ventilation system Swe	120	186	182176	-18373
Substitute refrigerator U.S.	0	0	370	-31
Automatic termination of clothes dryer U.S.	0	0	129	-12
Substituting heat pump U.S.	0	0	310	-29
Building design software U.S.	.	.	293600000000	-423775880
Refrigerator compressor U.S.	.	.	110100000000	-593286232
Electronic ballast U.S.	.	.	36700000000	-1186572463
Flame retention head oil burner U.S.	.	.	110100000000	-423775880
Low-emissivity windows U.S.	.	.	36700000000	-254265528
Substitute E05 --> biofuel 0-10 MW Swe	19000	40000	62704606	17758835
Substitute E05 --> biofuel 10-50 MW Swe	119000	172000	302929099	20363464
Substitute E05 --> E01 10-50 MW Swe	68000	137000	-17330040	3410675
Substitute E05 --> E01 50-100 MW Swe	147000	150000	-16740360	4355866
Substitute E05 --> tall oil 10-50 MW Swe	87000	102000	228756528	-4588855
Substitute E05 --> tall oil 50-100 MW Swe	191000,0	92000,0	220972752	-5860552
Substitute E05 --> wood-powder 10-50 MW Swe	226000	205000	303968901	186760
Substitute E05 --> wood-powder 50-100 MW Swe	232000	235000	293625914	238516
Substitute E01 --> tall oil 10-50 MW Swe	4000	-8000	246086568	-3724497
Substitute E01 --> tall oil 50-100 MW Swe	12000	-16000	237713112	-4429801
Substitute E01 --> wood-powder 10-50 MW Swe	35000	15000	321298941	-1480219
Substitute E01 --> wood-powder 50-100 MW Swe	23000	23000	310366274	-1760527
Substitute tall oil --> wood-powder 10-50 MW Swe	64000	47000	75212373	12528044
Substitute tall oil --> wood-powder 50-100 MW Swe	24000	83000	72653162	14935456
S.B.H. E01 --> biofuel/one dwelling house Swe	-7,25	-0,62	8257	-400

*EO5 = Swedish fuel oil, class 5, **EO1 = Swedish fuel oil, class 1

Appendix V. Data for the regression analysis for the agricultural sector.

Abatement measure	TM / NTM	Emission type	Removed emissions [ton]	Savings [€ *10^6]	Cost [€ *10^6]	Source
Immediate ploughing solid waste	NTM	NH3	300		0.2174	Cowell & Apsimon, 1998
Urea Substition	NTM	NH3	15300		20.00082	Cowell & Apsimon, 1998
Immediate ploughing solid waste	NTM	NH3	8900		13.58751	Cowell & Apsimon, 1998
Low-efficiency slurry application	TM	NH3	400		0.652201	Cowell & Apsimon, 1998
Imm. Ploughing of solid waste	NTM	NH3	3500		6.304606	Cowell & Apsimon, 1998
Immediate ploughing of slurry	NTM	NH3	100		0.2174	Cowell & Apsimon, 1998
Natural crust formation on slurry lagoons	TM	NH3	100		0.2174	Cowell & Apsimon, 1998
Low-efficiency slurry application	TM	NH3	1000		2.065302	Cowell & Apsimon, 1998
Natural crust formation of slurry lagoons	TM	NH3	600		1.413101	Cowell & Apsimon, 1998
Low-efficiency slurry application	TM	NH3	1500		3.478403	Cowell & Apsimon, 1998
Natural crust formation on slurry tanks	TM	NH3	200		0.4348	Cowell & Apsimon, 1998
Immediate ploughing of solid waste	NTM	NH3	5000		16.63112	Cowell & Apsimon, 1998
Immediate ploughing of solid waste	NTM	NH3	1900		6.304606	Cowell & Apsimon, 1998
High-efficiency slurry application	TM	NH3	300		1.304401	Cowell & Apsimon, 1998
Conversion to stilt housing	TM	NH3	3100		13.37011	Cowell & Apsimon, 1998
High-efficiency slurry application	TM	NH3	1600		6.956807	Cowell & Apsimon, 1998
Mid-efficiency slurry application	TM	NH3	200		1.087001	Cowell & Apsimon, 1998
Nipple-drinking systems	TM	NH3	1300		5.652405	Cowell & Apsimon, 1998
Mid-efficiency slurry application	TM	NH3	100		0.4348	Cowell & Apsimon, 1998
Low-tech covering for slurry tanks	TM	NH3	200		1.195701	Cowell & Apsimon, 1998
Scraper/sprinkler systems	TM	NH3	12600		392.4074	Cowell & Apsimon, 1998
Covered tanks for all slurry storage	TM	NH3	100		13.91361	Cowell & Apsimon, 1998
Covered tanks for all slurry storage	TM	NH3	600		102.8303	Cowell & Apsimon, 1998
Slurry aeration and flushing systems	TM	NH3	400		119.5701	Cowell & Apsimon, 1998
Under-floor drying systems	TM	NH3	400		132.3967	Cowell & Apsimon, 1998
Wetland restoration	NTM	N redu	5600		13.40388	Iversen, 1998
Groundwater protection areas	NTM	N redu	1900		12.0635	Iversen, 1998
Afforestation	NTM	N redu	1100		16.08466	Iversen, 1998
Livestock density requirements	NTM	N redu	300		4.021165	Iversen, 1998
Organic farming	TM	N redu	1700		24.12699	Iversen, 1998
Catch crops	NTM	N redu	3000		20.10583	Iversen, 1998
Requirements on nitrogen in animal manure	NTM	N redu	10600		26.80777	Iversen, 1998

Abatement measure	TM / NTM	Emission type	Removed emissions [ton]	Savings [€ *10^6]	Cost [€ *10^6]	Source
reduction 10% in nitrogen standards, crops	NTM	N redu	10500		15.01235	Iversen, 1998
covering stored layer manure	TM	NH3-N	59		0.014959	Webb et al., 2005
cove stored broiler manure	TM	NH3-N	55		0.014959	Webb et al., 2005
Immediate incorporation of pig slurry	NTM	NH3-N	770		0.400893	Webb et al., 2005
Crust formation on dairy slurry lagoons	TM	NH3-N	126		0.076289	Webb et al., 2005
Imm incorp layer manure by disc	NTM	NH3-N	658		0.429314	DEFRA, 2004
Imm incorp Broiler type manure by disc	NTM	NH3-N	1964		1.359745	DEFRA, 2004
Imm incorp Dairy cattle slurries by disc	NTM	NH3-N	3080		2.257267	DEFRA, 2004
Imm incorp beef cattle slurries by disc	NTM	NH3-N	554		0.41286	DEFRA, 2004
Imm incorp PIG FYM by disc	NTM	NH3-N	1046		0.810761	DEFRA, 2004
Imm incorp Beef cattle FYM by disc	NTM	NH3-N	4111		6.125585	DEFRA, 2004
Imm incorp Dairy cattle FYM by disc	NTM	NH3-N	1327		2.49511	DEFRA, 2004
Reducing the slatted area in pig buildings	TM	NH3-N	1197		48.2014	Webb et al., 2005
Litter drying systems for broiler houses	TM	NH3-N	1870		114.2186	Webb et al., 2005
Cover stored pig FYM	TM	NH3-N	65		7.400065	Webb et al., 2005
Cover stored beef FYM	TM	NH3-N	107		23.76637	Webb et al., 2005
Grass - Spreader Maintenance	NTM	Nfert	0.02	6.7E-06		Bates, 2001
Maize - Spreader Maintenance	NTM	Nfert	0.006	2E-06		Bates, 2001
Potato - Spreader Maintenance	NTM	Nfert	0.006	1.8E-06		Bates, 2001
Sugar beet - Spreader Maintenance	NTM	Nfert	0.002	3.8E-07		Bates, 2001
Wheat - Spreader Maintenance	NTM	Nfert	0.003	5.8E-07		Bates, 2001
Barley - Spreader Maintenance	NTM	Nfert	0.003	9.6E-07		Bates, 2001
Grass - Fertiliser free zone	NTM	Nfert	0.001	3.5E-07		Bates, 2001
Grass - Distribution Geometr	NTM	Nfert	0.004	1E-06		Bates, 2001
Maize - Distribution Geometr	NTM	Nfert	0.001	2.5E-07		Bates, 2001
Potato - Distribution Geometr	NTM	Nfert	0.002	4.3E-07		Bates, 2001
Sugar beet - Distribution Geometr	NTM	Nfert	0.001	1.3E-08		Bates, 2001
Wheat - Distribution Geometr	NTM	Nfert	0.001	1.8E-08		Bates, 2001
Barley - Distribution Geometr	NTM	Nfert	0.001	2.4E-07		Bates, 2001
Winter Wheat - precision farming	NTM	Nfert	0.02	6.4E-06		Bates, 2001
Spring Barley - precision farming	NTM	Nfert	0.01	1.3E-06		Bates, 2001
Grain Maize - precision farming	NTM	Nfert	0.015	3.2E-05		Bates, 2001
Wheat - Use Manure N	NTM	Nfert	0.018	5.2E-06		Bates, 2001
Potato - Use Manure N	NTM	Nfert	0.037		2.37E-07	Bates, 2001
Substitution of high-solvent to low-solvent prod	NTM	NH3	47130		40.76	http://www.iiasa.ac.at/web-apps/tap/RainsWeb/
Poultry, low ammonia application high efficiency	TM	NH3	3960		8.21	-"-
Laying hens, low ammonia application high efficiency	TM	NH3	50		0.12	-"-
Dairy cows, slurry systems,	TM	NH3	41990		193.84	-"-

Abatement measure	TM / NTM	Emission type	Removed emissions [ton]	Savings [€ *10^6]	Cost [€ *10^6]	Source
low ammonia application high efficiency						
Sheep & goats, slurry systems, low ammonia application high efficiency.	TM	NH3	2120		10	-"-
Dairy cows, slurry systems, low ammonia application + covered outdoor manure storage	TM	NH3	9820		50.81	-"-
Pigs, slurry systems, low ammonia application high efficiency.	TM	NH3	11220		76.18	-"-
Fertiliser production, combination of STRIP	TM	NH3	1070		7.48	-"-
Cattle, covered outdoor manure storage, high efficiency	TM	NH3	4690		33.09	-"-
Dairy cows, solid manure systems, low ammonia application, high efficiency	TM	NH3	2570		18.25	-"-
Pigs, solid manure system, low ammonia application, high efficiency	TM	NH3	2340		16.68	-"-
Other cattle, slurry systems, low ammonia application high efficiency	TM	NH3	4910		45.78	-"-
Other cattle, slurry systems, low ammonia application + covered outdoor manure storage	TM	NH3	8370		91.04	-"-
Other cattle, solid manure systems, low ammonia application high efficiency	TM	NH3	14680		194.1	-"-
Pigs, solid manure system, low ammonia application, high efficiency + low nitrogen feed	TM	NH3	540		10.29	-"-
Pigs, solid manure system, low ammonia application, high efficiency + biofiltration	TM	NH3	2570		50	-"-
Dairy cows, slurry systems, low ammonia application + animal house adaptation	TM	NH3	9980		217.07	-"-
Pigs, solid manure systems, biofiltration + low nitrogen feed + low ammonia application, high efficiency	TM	NH3	230		11.76	-"-
Other cattle, slurry systems, low ammonia application + animal house adaptation	TM	NH3	3390		250	-"-

Appendix VI. List of considered measures in the shipping sector

Measure abbreviation	**Full description**	**Main pollutant**
HAM	Humid Air Motor	NO_x
SCR	Selective Catalytic Reduction	NO_x
Fuel Shift from 2.9% to 0.5% S	Shift from bunker fuel (HFO) with 2.9 % Sulphur to bunker fuel with 0.5 % Sulphur	SO_2
Fuel shift HFO-MDO	Shift from Heavy Fuel Oil (HFO) with ~4 % S to Marine Diesel Oil (MDO) with ~2,5 % S	SO_2
Fuel shift to low sulphur fuel oil	Shift to HFO with low sulphur content	SO_2
Fuel shift to diesel oil <0.2% S	Shift to from HFO to MDO with sulphur content <0.2%	SO_2
Fuel shift to diesel oil <0.045% S	Shift from HFO to MDO with sulphur content <0.045%	SO_2
Improved fleet planning	Better utilisation of fleet capacity reduces fuel consumption	Fuel
Hull design	Optimisation of ship hull for less energy use	Fuel
Weather routing	Routing according to weather conditions affects fuel use.	Fuel
Just in time' routing	Reduced speed if the fuel-optimal speed is slower than max speed	Fuel
Optimal cargo handling	Reduced time in port can reduce fuel utilisation and improve ship utilisation	Fuel
Opt. Berth. Mooring anchor	Saving time in port can reduce speed at sea and lower fuel use	Fuel
Constant RPM	Steady power throughout a voyage decreases fuel consumption in comparison to current practice	Fuel
Optimal prop pitch	By varying the propeller pitch dependent on draft, speed and weather, fuel savings might be achieved.	Fuel
Minimum ballast	The ballast and extra bunkers are minimised to decrease weight of ship	Fuel
Optimal trim	Adjust the maximum speed to a given draft	Fuel
Optimal rudder	Reduce the variations in rudder angle saves fuel	Fuel

Appendix VII. Environmental effects of reduced energy demand

What are the environmental effects of reduced energy demand?

A common approach today is to allocate the environmental effects of reduced energy demand on the marginal production of energy. The motivation for this lie in that the effects of changes in energy demand will not affect all energy producers, only the producers that have the highest marginal cost of production, hence the marginal production. The concept of marginal production has been used in the core analysis in this project in order to illustrate the environmental effects of reduced energy demand. When using the concept of marginal production, one should take into account the time period and region that is considered. For this study, it has been shown as troublesome however to identify the marginal production of for example electricity, partly since background data on considered region and time-period is not considered in the data sets. In the core analysis of this study, the marginal production of electricity is assumed to originate from Danish coal power plants (ECON 2002). There are no available marginal values of heat production for the analysis however, so a Swedish average mix is used for heat instead. Table 6 lists the emission factors used for the emission calculations of energy-demand reducing measures.

It must be mentioned that in the core analysis, the emission factors for heat are adapted so that marginal electricity is used (instead of average electricity) in combination with the emission factors from biofuel, district heat and oil in the calculations on emission factors from heat production. Furthermore, the emission factors chosen for marginal electricity production from coal originates from coal condense power plants, which gives different emission factors than if coal combined power and heating stations would have been used for the calculation of emission factors.

Table 34: Emission factors, core analysis

The emission factors used for the core analysis.			
	Electricity[1] (Danish coal)	Heat[1] (Swedish mix)	
NOx	3.53E-04	3.40E-04	kg/kWh
SO2	5.76E-04	4.98E-04	kg/kWh
CO2	7.56E-01	2.78E-01	kg/kWh

[1] Adapted from Lindström 2005

The choice of production suitable as marginal production is not evident, and when it comes to measures that are implemented on a national scale, neither is the choice of marginal instead of average production. Furthermore, the choice of suitable emission factors is also of great concern for the outcome of the analysis.

The effect of these choices is analyzed in the sensitivity analysis. The emission factors used for the sensitivity analysis illustrate both the choice of marginal production as well as the effect of average production when calculating the effects.

There are three sets of scenarios that are compared with the core analysis.

1. Emission reductions are based on marginal production constituted by Gas condense power plants (Unger, 2003)
2. Emission reductions are based on marginal production constituted by Hydropower (Stripple, pers. comm., 2006)
3. Emission reductions are based on an approximation of average production

For all these three scenarios, the emission factors for heat are adjusted with the emission factors from a 50/50-nuclear/hydro electricity production in order to be closer to the Swedish average production of electricity.

Finally, in the core analyses and in two of the sensitivity analyses, the emission reductions are calculated using emission factors from marginal production of electricity and heat. These emission reductions are then compared with the total emissions from Sweden (STEM 2004). This causes a methodological problem, and this problem can be part of the reason to why the percent values of the emission reductions are very high for some of the analyses.

Table 35: Emission factors, sensitivity analysis

Emission factors used for the sensitivity analysis.					
	Electricity[3] (50% nuclear / 50% hydro)	**Heat[2]**	**Hydro[3]**	**Gas condense[2]**	
NOx	2.30E-05	2.60E-04	1.15E-05	4.32E-04	Kg/kWh
SO2	5.03E-05	3.75E-04	1.03E-05	1.44E-06	Kg/kWh
CO2	8.37E-03	9.75E-02	3.76E-03	3.76E-01	Kg/kWh

[2] (Uppenberg et al., 1999)
[3] (Baumann & Tillman, 2004)