USING "MOSES" FOR ASSESSMENT OF COSTS AND COST EFFECTIVENESS OF ENVIRONMENTAL POLICY

Some Applications

Paper prepared for the "Workshop on techno-economical databases on production processes and related emission abatement options", Angers (France), 28-29 October 1999.

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1 INTRODUCTION

MOSES, the Model On Sustainable Environmental economic Scenarios is developed in 1992 by the Institute for Applied Environmental Economics (TME), The Hague, The Netherlands. MOSES is a spreadsheet model and enables interactive and target driven cost-assessment of environmental policies. Costs and investments are calculated at source level[1] and are the result of required or cost-minimising policies to reduce emissions.

Originally MOSES was developed as a model that should give hard evidence for the cost-advantages of a market based policy.

This choice was also decisive for the design of the model. It was decided that MOSES should enable the user to incorporate databases with all relevant data on emission sources. To enable assessment of market driven policies, cost functions should be marginal, if possible already at enterprise level (source). Moreover it was decided that MOSES should work at a the level of polluting substances:

- Waste water: COD, P-tot, N-tot, heavy metals;
- Air: SO2, NOx, PMT, VOC;
- Waste: non-hazardous waste, hazardous waste.

Over the last seven years MOSES has been applied in many cases and situations. It has proven to be a flexible and relatively fast applicable tool to make a variety of environmental economic assessments.

1.1 Organisation of this paper

This paper gives an overview of some of the experiences with the application of MOSES. Before summarising these applications a short section deals with the basic design of MOSES. This is followed by 4 sections on the application of MOSES in different cases:

- estimate of costs and investments to reduce SO2 and NOx emission of large sources in the oil-, chemical, base metal and power sector in the Netherlands to reduce emissions to a given ceiling;
- optimisation of the use of economic tools (emission tax) in Slovakia;
- cost-assessment of compliance with the EU Large Combustion Plants directive in Poland;
- assessment of cost-effective reduction strategies for fine particles in Europe.

1.2 MOSES information

In the future, more information on MOSES (reports, databases etc.) will be added to the TME website (www.tme.nu).

It is also foreseen that a demo-version of MOSES (in Excel) will be available from this website (planning: end 2001).

[1] A “source” can be a stack/boiler, or a household, an enterprise, or comparable (to a sudden degree) sources.

2 THE "MOSES" MODEL

2.1 Why MOSES was developed

The MOSES model was developed on demand of the Worldbank. The aim was to create a model that enables assessment of the cost-advantage of the application of Market Based Instruments (MBI) in environmental policy compared to a regulatory approach. Therefore, such a model should include:

- emissions of (preferably) individual sources;
- emission reduction targets, inducing the use of environmental technologies;
- data on costs of emission reduction technologies ("control costs", "abatement costs").

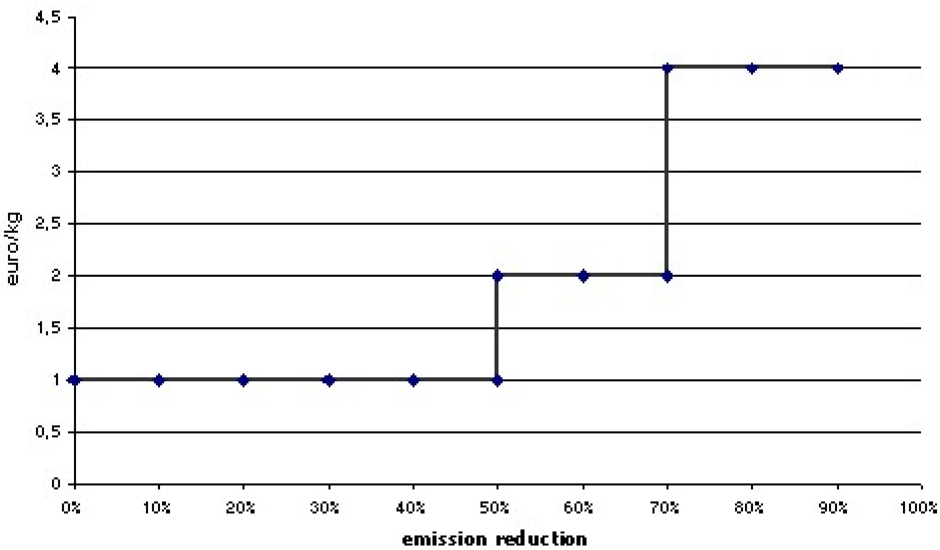
It should be possible to implement targets of environmental policy in a flexible way:

- on the one hand definition of reduction targets for each individual source should be possible;
- on the other hand it should be possible to simulate the effects of an emission tax on emission(reduction) and control costs.

TME was asked by the Worldbank to develop such a model, in the spreadsheet model LOTUS 123 (as to enable use of the model by recipients). The reason that TME was selected to develop this model was the experience TME had in developing a costing model for the Dutch Environmental Policy Plan (VROM, 1989; Jantzen, 1989; RIVM, 1989).

2.2 Basic design of MOSES

The basic design of MOSES is simple. The idea is that for each pollution source, a marginal control (abatement) cost-function can be created. Costs in this function are related to emission abatement and expressed in monetary units per unit of emission reduction. By creating these marginal cost functions for each source (in a case study) it is possible to rank technological options according to cost-effectiveness. A simplified marginal cost function is shown in the following figure.



In the figure a three-step abatement cost function is shown:

- the first step reduces 50% of emissions at costs of € 1 per kg;

- the second step reduces emission from 50-70% at costs of € 2 per kg;
- the last step reduces emission up to 90% at marginal costs of € 4 per kg.

If environmental policy makes use of regulation costs for this source, calculations are as follows:
- assume an unabated emission of 100 kg and a reduction target of 60%;
- costs of reduction are:
  - technology 1: 50kg * € 1/kg = € 50;
  - technology 2: 10kg * € 2/kg = € 20;
  - total costs: € 70.

If a tax or another market-based instrument is applied costs can be assessed as follows (assuming that the polluter tries to minimise pollution costs):
- assume a tax of € 1.5 per kg;
- costs of reduction are:
  - technology 1: 50kg * € 1/kg = € 50;
  - (no further technologies are used, since paying tax would be cheaper than to abate additional emissions with technology 2 (at € 2 per kg);
- tax costs are:
  - (100-50)kg * € 1.5 per kg = € 75.

In this case MOSES selects all technologies that are cheaper than € 1.5/kg, e.g. the first step of the pollution abatement curve.
It can be seen easily that a tax of for example € 2.5/kg would lead to a reduction of 70 kg.

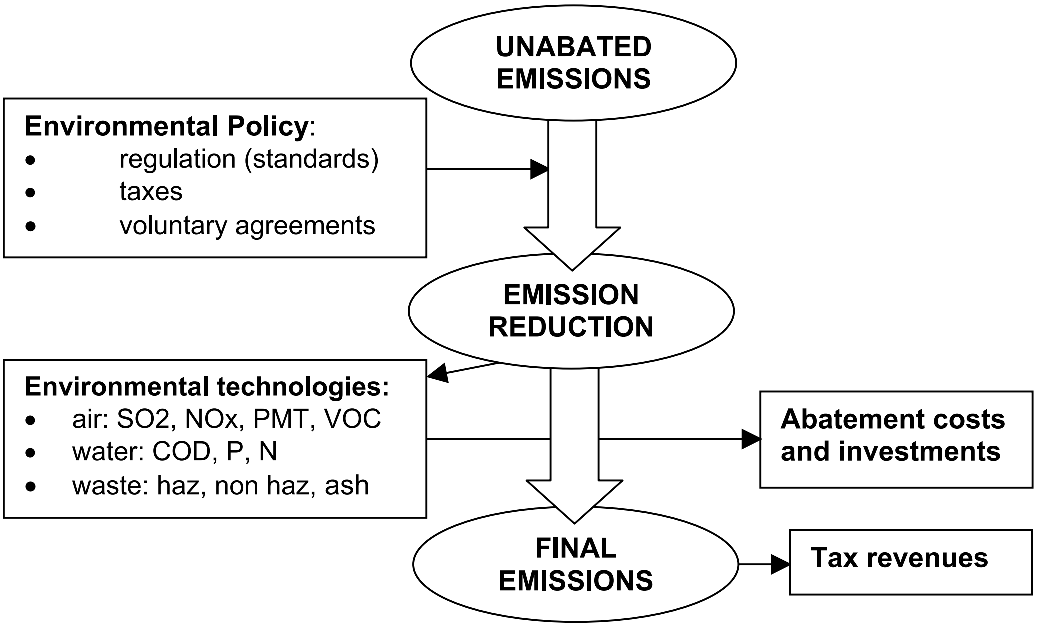
Normally many pollution sources are included in a case study. For each pollution source a marginal cost function can be estimated. These cost-functions are different for different sources.

In a case study, MOSES calculates for each source the costs of emission reduction to achieve a given reduction target. Emission reduction can be defined at source level, at case study level, but it could also be the result of the application of an emission tax (assuming cost minimising behaviour by polluters).

2.3 Elements in MOSES

Given the basic design and functioning of MOSES the following information is required:
- definition of sources, collection of data describing these sources (emissions, development thereof; reduction targets (to be derived from standards, for current situation from actual reduction achieved by applying a technology); technologies (as a marginal cost function);
- technology databases (there are standardised technology databases for SO2, NOx, PM10, VOC, COD, P-tot, N-tot, heavy metals, Non hazardous waste, Hazardous waste, Ash). Either standard technology databases can be used or a case specific technology database can be created by the user;
- definition of environmental policy. MOSES allows the following types of simulation:
  - regulation at case level (i.e. 50% reduction for each source);
  - source specific regulation (for each source a reduction target is calculated based on for example current fluegas concentrations of the pollutant and needed concentrations as described by regulations);
  - a combination of both (to assess future policy);
  - an emission tax (expressed in € per kg);
  - a combination of source specific targets (to be achieved anyway) and an emission tax.

The following figure gives an overview of the functioning of MOSES at source level



For each source first unabated emissions are estimated. Next, emission reduction is calculated. This is the result of the implementation of environmental policy. To achieve emission reduction, environmental technologies need to be applied. The user therefore has to define which technologies (in a marginal way) can be applied (in principle) to the source ("string of technologies"). Given a certain emission reduction target at source level, MOSES selects the technologies (from the already defined "string of technologies") that are needed to achieve the required emission reduction. Alternatively (in case of the application of market based incentives), MOSES selects the technologies that are cheaper to implement than to pay an emission tax (marginal abatement costs are lower than the tax rate).

By multiplying for each technology the abated emissions (with the technology) with standardised costs of the technology, total costs to apply the technology are calculated. By summing the multiplication for each technology (for one source) total abatement costs (and investments) for one source are calculated.
If an emission tax is applied, MOSES also calculates the payments/revenues from such a tax, by multiplying final emissions (the "tax base") with the tax rate.

3 NETHERLANDS: POTENTIAL COST SAVINGS OF A SYSTEM OF TRADABLE PERMITS FOR LARGE INDUSTRIAL SOURCES

This chapter is based on the English summary of the report "Kiezen voor Winst" ("Choose for profit"), partly written by Heddeke Heijnes (TME, 1997b).

3.1 Introduction

A possible tool to give companies more possibilities in the area of emission reduction policy is a system of Tradable Emission Permits (TEP), which offers companies more flexibility as compared to regulation and standards on installation-level. In a system of tradable emission permits, emitters of pollutants obtain 'permits' for a certain level of emission. They can exchange these permits with other participants. In this way, a market is created for the purchase and sale of emission permits, and the environmental policy is turned into an economic issue.

The Inter Provincial Council (Inter Provinciaal Overleg, IPO) has asked the Institute for Applied Environmental Economics (Instituut voor Toegepaste Milieu-Economie, TME), in co-operation with Tebodin, Grontmij and the University of Groningen to investigate the potential cost-advantages of such a system.

3.2 Objective

The objective of the investigation is to determine the *total potential cost advantages for companies* in an TEP system in comparison with a system of regulation on installation level (hereafter referred to as "Regulation") on the basis of cost and emission data that have been collected from practice. The investigation aims specifically at environmental measures for NO_x and SO_2 for four business sectors: the Chemical sector, the Base metal sector, the Refinery sector and the Electricity production sector. These sectors give an important contribution to the total stationary emissions of NO_x and SO_2 in the Netherlands.

Next to abatement costs of the "Regulation scenario", that can be regarded as a baseline scenario for four different system variants of environmental policy making use of TEP, have been investigated:

- internal trade within a company (the location of a company as a separate entity);
- internal trade within a group of companies (a group of companies as a separate entity);
- external trade of permits within a sector with sectoral emission maximums (Sectoral Trade);
- external trade of permits between sectors with a suprasectoral emission maximum (Suprasectoral Trade).

3.3 Starting Points

1. *Issue of data by companies:* The investigation is based on the statement of emissions, measures to reduce emission and the costs involved, determined in consultation with the companies that have participated in the investigation (Tebodin, 1996). Table 1 shows a survey of the number of companies in the investigation and the extent to which the emissions in the inventory are covered.

2. *Emission ceilings 2010:* National NEPP reduction targets have been translated to emission standards on installation-level by the Ministry of Housing, Spatial Planning and Environment (VROM, 1996a). These standards indicate the maximum emission concentrations per installation or source of emission in a system of regulation.

Based on these standards, the maximal allowed NO_x and SO_2 emissions (incineration and process emissions) have been calculated for the companies involved, thus also allowing for the calculation of (supra)sectoral emission ceilings.

3. *Technical conditions:* Only reduction techniques that are known and tested have been taken into consideration (low NO_x burners, SCR installations). Additional costs for the installation or adaptation of existing installations ('retrofit' costs) have been taken into account.

Table 1. Survey of the extent to which emissions are covered by the investigation (company emissions/total sector emissions) in 1995

Sector	Number of companies in investigation	Number of emission sources in investigation	Total emissions sector 1995 (kton/a)		Emission in investigation (kton/a)		Coverage of emissions (%)	
			NO_x	SO_2	NO_x	SO_2	NO_x	SO_2
Base metal	7	112	9.0	11.4	8.8	10.6	97%	93%
Chemistry	26	241	22.2	11.0	19.6	8.7	88%	79%
Refinery	5	44	16.9	60.7	15.4	52.5	91%	87%
Electricity	4	55	48.9	16.2	48.9	16.2	100%	100%

3.4 Assessment of cost-advantage

For the assessment of the cost-advantage MOSES was used. For this purpose the data collected at company level, together with engineering information for each source, emissions, emission reducing technologies and the cost thereof have been estimated and transformed into databases that can be used in MOSES.

3.5 Uncertainties

The results of this study is limited by some uncertainties:

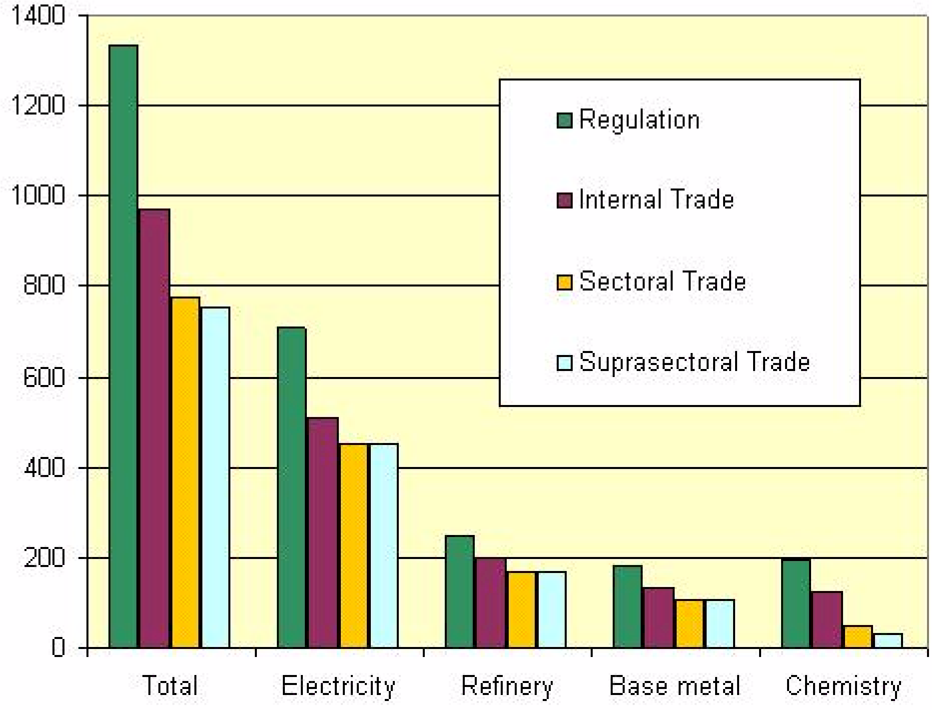
- costs are based on statements by companies, which have been validated by the researchers. Retrofit-factors varying from 2 to 7 have been found. Due to this, costs in this study are higher than the costs for comparable measures in other studies, in which retrofit has not been taken into account;
- technological developments has not been taken into account. In the long run, this may also result in lower control costs;
- the study only covers the companies in the sample;
- aspects related to the introduction and application of a TEP system, such as administrative, transaction and implementation costs, (incomplete) knowledge of market parties, strategic behaviour of companies, and employment of different criteria for investment decisions in business economics have been disregarded.

3.6 Results NO_x

In figure 1, the results of the calculations for NO_x are shown. The figure states the total and the net costs per sector that companies in these sectors will have to make. That is to say the costs related to their environmental measures (costs for exploitation per annum); it also states the costs or income resulting from the purchase or sale of emission permits.

It becomes clear from figure 1 that the costs for realisation of emission reduction decrease substantially, as more flexibility is possible. The bar on the left-hand side states the net costs in case of Regulation. The total annual net costs in the case of regulation amount to Dfl 1335 mln. (Dfl 1 = € 0.45) in the year 2010. In the case of Internal Trade the total annual net costs amount to Dfl 971 mln., approximately 30% lower in comparison to Regulation.

Figure 1: Annual costs (Dfl) for NO_x control for the system variants in 2010



The transition to emission trade on sector-level results in a decrease in costs of 19% for all four sectors together. Trade in emission permits on a suprasectoral level, that is to say in a situation in which all companies in the four sectors are able to trade with each other, results in a minor cost reduction in comparison to the trade in emission permits per sector. This system variant offers most flexibility by far for the companies involved, which is mirrored by the fact that this variant has the lowest control costs (23% instead of 19% advantage as compared to internal trade). The advantages per variant differ per sector.

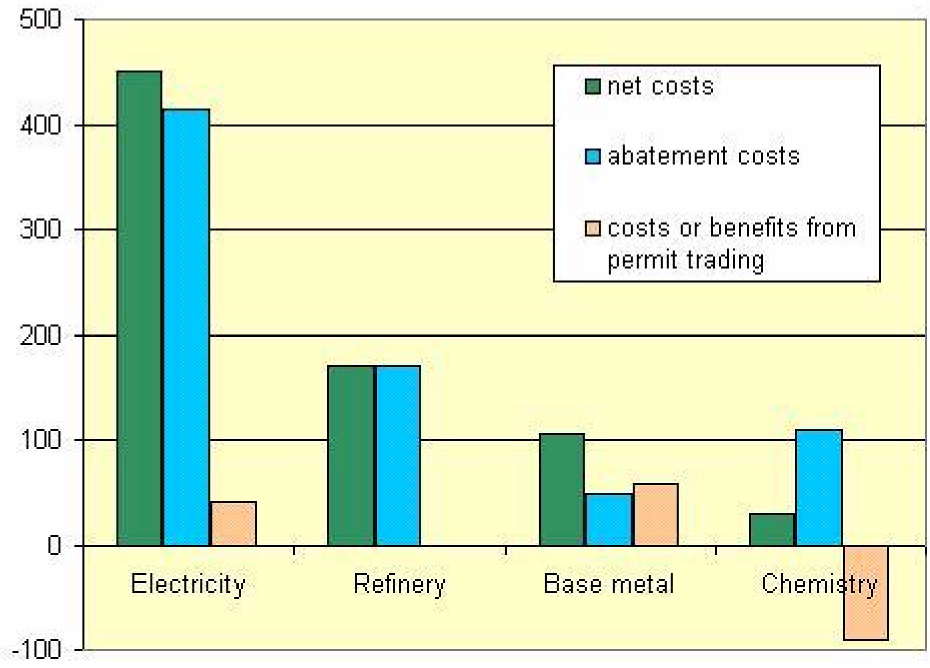
Base metal already achieves the greatest cost advantage in a transition to Internal Trade. The exchange between installations already realises a cost reduction of approximately Dfl 50 mln. per year. This advantage is realised for the greatest part by one company. The transition to Sectoral Trade results in a cost reduction of approximately Dfl 27 mln. per year. Suprasectoral Trade results in hardly any extra cost reduction.

The **Chemical sector** achieves the most important cost reduction in the transition to Internal Trade (approximately Dfl 70 mln.) and the transition to Sectoral trade (approximately Dfl 80 mln.). In the case of Internal Trade, the advantages are mostly for the benefit of larger companies that have more emission sources of various sizes at their disposal. These companies do achieve advantages in Sectoral Trade, in which smaller companies can optimise their measures in co-operation with other companies. The Chemical sector also achieves a considerable cost reduction in the transition to Suprasectoral Trade. The Chemical sector can control emissions relatively cheaply, considerably cheaper than the other sectors. In this particular variant, the Chemical sector realises an extra emission reduction, thus taking extra measures (costs approximately Dfl 110 mln. per annum) for which TEP's can be sold with a profit of approximately Dfl 90 mln. per annum. The net control costs are therefore considerably lower (Dfl. 21 mln. per annum).

In absolute terms, the **Electricity production sector** gains most advantage from a TEP system, obviously because this sector is forced to make most costs. The cost advantage is already realised for the greatest part in the transition to Internal Trade. The transition to Sectoral Trade produces relatively little profit, because there is little variation in the costs for the measures the different electricity companies have to take.

The **Refineries** obtain the most important advantage in Internal Trade. The possibility to 'exchange' emissions between the installations within a refinery gives an important contribution to cost optimisation, the cost advantage amounting to approximately Dfl 43 mln. per year. Sectoral trade gives a lower advantage. In case of Suprasectoral Trade, the Refinery sector sells emission permits to the electricity production sector and the Base metal sector. Like the other sectors, the Refinery sector reaches the emission ceiling more easily when more trade is possible.

Figure 2: Costs and benefits (Dfl) from Suprasectoral Trade in NO_x emission permits



The net costs (left bar for each sector) consists of the sum of the costs for exploitation in connection with the measures for control (middle bar), and the costs or income related to the purchase or sale of TEP's (right bar).

In Suprasectoral Trade the Refinery and the Chemical sector will take extra measures for control in return for which they get income from the sale of TEP's. The purchase or sale of emission permits for NO_x by Base metal and the Chemical sector respectively is caused by the high control costs: Base metal has high control costs which makes it interesting to buy emission permits. The Chemical sector therefore has a net income from the sale of emission permits: the income from the TEP-trade is higher than the costs for extra control measures.

3.7 Conclusions

1. A system of Tradable Permits of Emission (TEP's) offers substantial possibilities to decrease the costs for environmental measures for the business community, while the business community remains below the emission ceilings. The residual emissions, however, are higher in the TEP variants than in the case of Regulation and Internal Trade.
   The cost advantages are potentially very high, in many cases over 50% of the costs of regulation. This is caused mainly by the fact that the marginal control costs for the compulsory measures of Regulation are high in the case of high targets (80% reduction). These measures are not always taken in a TEP system because 'exchange' becomes possible with other installations or companies that are able to control cheaper.

2. Nearly all companies may benefit from an increase in flexibility. Internal Trade with emission ceilings on the level of a company or group of companies offers this flexibility. It also offers potential cost advantages as compared to regulation, especially to larger companies with more sources of a different nature.

3. The greatest advantages can be obtained in a TEP system with External Trade. Nearly all companies can obtain a potential advantage from a TEP system. Companies that have relatively high control costs will stop reducing and buy TEP's instead, for a lower price than their marginal control costs. Companies with relatively low control costs will increase their control and will sell their emission permits to companies with higher control costs. If the price of emission permits is substantially higher than their internal marginal control costs, companies can even achieve a net profit from their trade in emission permits. Thus, TEP offers companies the possibility to achieve cost optimisation of emission reduction.

4 SLOVAK REPUBLIC: "REVENUE MODEL"

This chapter is based on work carried out for the EU Phare programme in the Slovak Republic, "Economic Instruments for Environmental Policy in the Slovak Republic" (Jantzen, 1997).

4.1 Introduction

In 1996-1997 TME participated in a Phare project on Economic Instruments in Slovakia (Jantzen, 1997). One of the aims of the project was to build a revenue model. This model should enable the estimates of revenues of environmental charges/taxes applied in the Slovak Republic

For this purpose the MOSES-model has been used. As explained earlier MOSES interactively estimates:
- emissions;
- emission reductions;
- emission control costs;
- tax revenues.

Because marginal control costs functions for each source are modelled in MOSES, it is possible to simulate the primary effect of emission taxes/charges. In MOSES it is assumed that an enterprise (polluter) will abate emissions by two mechanisms:
- by complying with legal standards (for example concentration standards for fluegas emissions)
- by reacting to an emission tax: if the tax rate (per kg/NOx) is higher than the marginal costs of an emission abatement measure the enterprise will implement this measure (it would lower the costs for environment).

By applying MOSES in a given situation it is possible to estimate how high emission abatement costs are and what the (emission reduction) effect of emission taxes would be (assuming economic rational cost-minimising behaviour of firms).

The general belief is that by taxing emissions the emissions will decrease. The result of this would be that less tax revenues are generated than anticipated. Therefore, an emission tax is believed to be NOT APPLICABLE for revenue generation in the long term. It is therefore excluded in most "green tax" plans in EU-member states.

In this specific case MOSES has been used to estimate revenues for different tax levels (a tax on NOx). Main purpose of this calculation has been to show that emission taxes also can serve as a stable tax base to generate tax revenues.

4.2 Modelling Slovak emission sources

Essential in the use of MOSES is that emission sources are modelled in a sound way. For Slovakia this turned out to be "very possible". Of the Slovak Hydrometereological Institute a database on the largest (air) polluting sources was obtained (used for the CORINAIR system). This database comprises information on about 50 enterprises with in total more than 500 stacks.

For each stack or enterprise the following information is available:
- name, geographical position;
- energy input, type of fuel;
- emissions of SO2, NOx, CO and particles;

- thermal capacity;
- type of boiler.

This “sources”-database is extended with information of applicable environmental technologies per emission source. This information is stored in standardised “technology”- databases of MOSES. Moreover the Slovak emission standards for air have been incorporated in the “sources”-database as to assess the needed emission reductions for each individual source. The next step has been to transform the information in such a way that it can be applied in MOSES.

4.3 Estimating tax revenues

To estimate tax revenues different tax levels have been used in the simulations. The following table gives these rates:

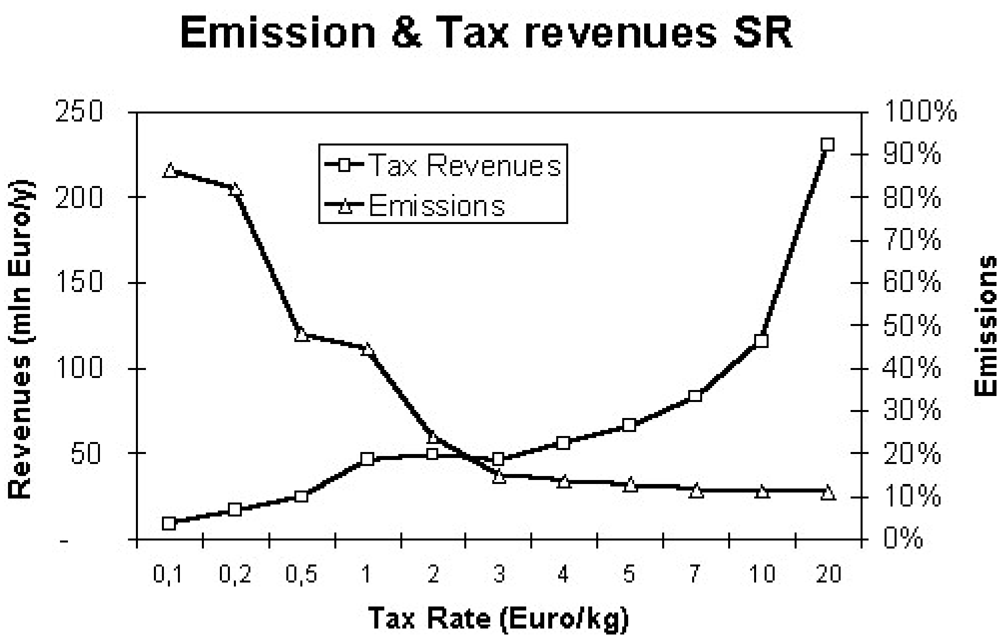
charge rate	€/kg	0.1	0.2	0.5	1	2	3	4	5	7	10	20

For comparison: the current charge rate for NOx is about 0.02 €/kg in Slovakia.

By using the above mentioned tax rates as input in MOSES it can be estimated what will be the emission reduction (as a result of cost-minimising behaviour of firms) and thus the final emissions (after abatement). It therefore estimates the tax base, by multiplying final emissions with the tax rate, total annual tax revenues can be estimated.

The simulations have been carried out for 2010.

The resulting final emissions and tax revenues for the different tax rates are shown in the next figure.



This graph shows that although the tax base decreases as a result of the emission tax, the total revenues of the tax increase as the rate increases. So the drop in the tax base is more than compensated by the higher tax rates. Only for rates between 1 and 3 € per kg tax revenues remain stable. For these rates emissions are reduced from about 50% of unabated emissions to about 15%. But because the tax rate triples, total revenues remain the same (about € 50 million).

If the current tax rate (for NOx about 0.02 €/kg) would in 2010 still be used, and no standards would be implemented the revenues would be about € 2 million. So it can be seen that the potential tax revenue for a NOx tax in Slovakia is much higher.

As a general conclusion it can be stated that given the current low tax rate for NOx in Slovakia, revenues of emission taxes can be increased enormously (more than 25 times higher) by increasing the tax rate. The fear for the "incentive effect" (thus decreasing the tax base) that would "dry-up" the tax base is shown not to be realistic.

4.4 Applying emission standards in Slovakia

As is the case in most countries, Slovakia has developed a legal system of concentration standards for air polluting substances. This means that given certain characteristics of a source (thermal capacity, type of boiler, fuel used) maximal allowed concentrations of pollutants in flue gasses are defined.

The next table gives an indication on what may happen if the Slovak standards for NOx would be applied in 2010. Next to emissions, emission reduction, final emissions and also annual costs and needed investments that the various sectors should have to make are shown in the table.

Table 2: Emissions, emission reduction, final emission, annual costs and total investments needed when emission standards for NOx are implemented in Slovakia (2010)

Sector	Unabated emissions	Emission reduction	Final Emissions	Annual abatement costs	Total Investment needed
	kton/y	kton/y	Kton/y	€ mln	€ mln
Food & Beverages	0.76	0.37	0.39	0.20	1.27
Textile	0.49	0.21	0.28	0.25	1.60
Wood processing	0.10	0.00	0.10	0.00	0.00
Paper	4.92	1.71	3.22	0.88	4.95
Refineries	6.66	2.91	3.75	2.57	14.37
Chemical, basic	1.12	0.54	0.59	0.12	0.72
Chemical, fertiliser	2.44	1.45	0.99	4.35	20.96
Chemical, other	3.09	1.47	1.62	0.47	2.85
Building materials	0.85	0.12	0.73	0.04	0.27
Base Metal, ferro	40.48	24.68	15.80	16.75	81.78
Base Metal, non-ferro	0.34	0.09	0.26	0.20	0.88
Metal Industry	0.93	0.38	0.55	0.01	0.06
Other Industries	0.27	0.00	0.27	0.00	0.01
Power, coal	1.53	1.23	0.30	0.18	0.74
Power, lignite	19.29	9.03	10.26	0.08	0.36
Power, gas	8.44	6.67	1.77	4.29	18.74
Power, oil	0.72	0.42	0.30	0.85	5.27
Power, other	10.51	4.59	5.92	3.61	20.24
TOTAL	102.94	55.86	47.08	34.84	175.08

source: TME, 1999, based on database of air polluting sources in Slovakia.

It can be seen that the application of emission reduction charges in Slovakia could lead to an emission reduction of about 55% in 2010. Total annual costs would be about € 35 million, total investments about € 175 million.

To show what the effect of the application of market based instrument might be (as an emission charge/tax or tradable permit), simulations have been carried out assuming that - instead of implementing emission standards - an emission tax would be imposed that would lead to the same amount of emissions in 2010. The simulation shows that this would be the case at a tax rate of between € 0.5 and € 1 per kilogram. Taking the rate of € 1 per kg the following results are obtained:

Table 3: Emissions, emission reduction, final emission, annual costs and total investments needed when a tax of € 1 per kg NOx (no emission standards) would be implemented in Slovakia (2010)

Sector	Unabated emissions	Emission reduction	Final Emissions	Annual abatement costs	Total Investment needed
	kton/y	kton/y	kton/y	€ mln	€ mln
Food & Beverages	0.76	0.48	0.28	0.12	0.68
Textile	0.49	0.20	0.29	0.13	0.89
Wood processing	0.10	0.09	0.01	0.02	0.06
Paper	4.92	2.71	2.21	0.80	5.08
Refineries	6.66	2.97	3.70	1.03	7.16
Chemical, basic	1.12	0.94	0.18	0.16	0.68
Chemical, fertiliser	2.44	0.55	1.89	0.15	1.05
Chemical, other	3.09	2.38	0.71	0.41	1.83
Building materials	0.85	0.38	0.47	0.11	0.75
Base Metal, ferro	40.48	18.29	22.18	6.05	41.82
Base Metal, non-ferro	0.34	0.02	0.32	0.01	0.10
Metal Industry	0.93	0.78	0.15	0.12	0.52
Other Industries	0.27	0.24	0.03	0.03	0.12
Power, coal	1.53	1.35	0.18	0.27	0.98
Power, lignite	19.29	16.93	2.35	2.35	7.79
Power, gas	8.44	3.80	4.64	1.05	7.28
Power, oil	0.72	0.29	0.43	0.19	1.30
Power, other	10.51	4.73	5.78	1.30	9.07
TOTAL	102.94	57.14	45.81	14.29	87.16

source: TME, 1999, based on database of air polluting sources in Slovakia.

Comparing the results from the last two tables the following observations can be made:

- in both cases emission of NOx in 2010 would be reduced to less than 50,000 tons per year;
- emission reduction in the case of the application of an emission tax would be slightly larger than by applying source specific standards;
- annual abatement costs (excluding the costs imposed on firms by the emission tax) would be about € 14 million in case of an emission tax, € 35 million in case of source specific standards;
- total investments could be halved by applying a tax in stead of standards (€ 87 million instead of € 185 million).

These calculations show that implementation of emission taxes would not only generate a stable stream of revenues, but it also would be an efficient instrument to reduce emissions. Annual costs could be reduced by 60%, investments could be halved.

5 COST OF COMPLIANCE WITH EU-ENVIRONMENTAL DIRECTIVES IN CEEC'S

This chapter is mainly based on the Phare-DISAE project (POL-101)

5.1 Introduction

During the period 1996-1999 MOSES was used in various assignments in Central and Eastern European Countries (CEEC's) to estimate costs of compliance with main environmental directives in terms of costs. In total 5 such studies were carried out in:

- Poland;
- The Baltic States (Lithuania, Estonia, Latvia);
- Ukraine.

In the first four studies for all main EU directives estimates of costs were made. In Ukraine only the Large Combustion Plants directive was assessed.

Cost assessments with MOSES were made for:

- the Large Combustion Plants directive;
- the Urban Waste Water Directive;
- the Landfill Directive;
- the Packaging directive;
- (only in Lithuania) the VOC Directive.

Although the main issue to be addressed in these studies was the calculation of the total costs of approximation, in some cases use was made of the ability of MOSES to estimate the difference between a "regulatory" approach and a "least cost" approach.

In this chapter examples will be given of cost-estimates for the Large Combustion Plants Directive in Poland. First the general approach and definitions used in these studies will be discussed briefly.

5.2 Approach

For the assessment of costs and investments of approximation the following activities have been undertaken:

1. Definition and estimation of the "approximation gap";
2. Estimation of "unit costs", including "unit investments";
3. Multiplication of both to assess total costs/investments.

The "approximation gap" describes the "physical" requirements to comply with EU directives. It describes the difference between the actual and the required situation concerning the implementation of measures. This may be - for example -: (a) the additional number of connections to sewerage, (b) the difference between an emission factor and an emission standard or (c) the obligation to collect 75% of biodegradable household waste separately.

"Unit costs" have been estimated as - for example -: (a) the costs of one additional connection to sewerage; (b) the marginal (additional) costs to reduce one kilogram of emissions or (c) the additional costs to collect and compost one ton of biodegradable waste.

In most cases the estimated "unit costs" are expressed in EU price level, which in general is higher than the local prices. In some cases local prices have been used or have been reported.

Multiplication of unit costs with the assessed "approximation gap", results in the estimation of annual costs for the year calculations are carried out. These annual costs include the annualised investment costs (estimated by using the "annuity"). To annualise investments an interest rate of 8% has been applied.

To avoid various methodological difficulties the "Costs of approximation" have been defined as the difference of the total costs and investments in the year of reporting (for example 2000, 2005, 2010) and the base year (depending on data availability, 1995, 1996 or 1997). This implies that for each of the directives the total costs and investments have been estimated for the base year (if appropriate) and for some year of the approximation period. The difference between the both is than addressed to the "approximation".

Due to this definition it is possible that the costs of approximation include part of the costs of the national environmental policy or strategy. It also should be clear that the costs reported are additional to what already has been achieved by 1995-1997.

To use MOSES, for each (major) source of pollution the unabated emissions (present and future) and needed emission reductions (as % of unabated emissions) have been modelled (based on statistics and other information sources and the requirements of the directives). Also the applicable environmental technologies to reduce emissions have been selected from the MOSES-databases and linked to the defined sources.

For the assessment of the Large Combustion Plants Directive all plants (often with information at stack or even boiler level) have been modelled in a database, taking into account type of fuel, (thermal) capacity, emissions, emission factors, flue gas concentrations. If necessary restructure of the energy sector was taken into account.

For the assessment of the Urban WasteWater Directive, databases were made including over 90% of the relevant communities, number of inhabitants, connection rates to sewerage and type and capacity of wastewater treatment (if any). For all these plants the current situation was compared (plant by plant) to the required (which is difficult because the directive makes a distinction between sensitive and non-sensitive areas).

For the Landfill and Packaging Directives less detailed information was available[2]. These figures were subdivided in waste components, since both directives imply reduction targets for certain waste components. For biodegradables (in 2010): 75% compared to 1993 levels; for packaging waste the requirement is that from 2005 onwards, 50% of the total amount of generated packaging waste is recovered. For each packaging component also a requirement exists of 15% recovery.

5.3 Large Combustion Plants Directive (>50 MWTh): implementation in Poland

The requirements for emission reduction of the Large Combustion Plant (LCP) Directive (88/609/EEC) are twofold:

- Emissions of SO_2 (sulphur dioxide) and NO_x (nitrogen oxides) from existing sources must be reduced (compared to 1980 levels);

[2] In most cases only rough estimates of National waste arisings were available.

- New sources (those constructed after June 1987, or plants with major changes) must comply with emission standards for SO_2, NO_x and particles.

In Poland, also the requirements of the second sulphur protocol have to be taken into account.

A complication is that the second sulphur protocol relates to total emissions, whereas the large combustion plants directive makes a division between existing and new sources.

To avoid complicated calculations and assumptions concerning existing versus new sources the following approach for emission reduction has been used:
- for ‘new’ sources the requirements of the directive have been applied;
- the total emissions for all sources regarded have to comply with the requirements of the second sulphur protocol.

New sources
For new sources the following emission standards apply:
- SO_2 : solid fuel: between 2000 mg/Nm^3 at 100 MWth and 400 mg/Nm^3 at 500 MWth; liquid fuel: 1700 mg/Nm^3 for plants between 50-300 MWth and between 1700 mg/Nm^3 at 300 MWth and 400 mg/Nm^3 at 500 MWth; gaseous fuel 35 mg/Nm^3;
- NO_x : solid fuel: 650 mg/Nm^3 , liquid fuel: 450 mg/Nm^3 and gaseous fuels 350 mg/Nm^3;
- Particles: solid fuel: 50 mg/Nm^3 if thermal capacity is > 500 MW, 100 mg/Nm^3 if thermal capacity is <500 MW; liquid fuel 50 mg/Nm^3 ; gaseous fuel 5 mg/Nm^3.

In this case ‘reduction targets’ at source level were introduced in MOSES. These targets are either related to the technologies (to be) applied (as stated in Jankowski, 1998, p. 37) or (in case of new industrial plants) are calculated by comparing the standards with the unabated emission factors (taken from ESC, 1988). This results in needed emission reduction for each source.

Emission ceiling
The emission ceilings are calculated from the requirements of the second sulphur protocol. This requires the following (general) emission reductions (in relation to 1980 emissions):
- 2000: 37%;
- 2005: 47%;
- 2010 and onwards: 66%.

The calculated ceilings for total emissions of SO_2 and NO_x are summarised in the next table.

Table 4: Estimated emission ceilings for SO_2 and NO_x in Poland (in kilotons/y)

	2000	2005	2010
SO2	1 363	1 146	735
NOx	438	368	236

source: own estimation

5.3.1 Methodology

To assess the costs and investments of the requirements of this directive an overview has been made of thermal power plants, and a limited number of other large industrial sources with a capacity of more than 50 MWth. Data collected are:
- annual emissions in 1996 and emission factors (SO_2, NO_x, particles) of existing plants in the power sector;
- annual emissions in 1996 (and years before) of the largest industrial plants;
- division of capacities of industrial boilers in industry;

- fuel use and type of fuel (in case of power plants);
- development of fuel input in the future (see 2).

Since a major part of the directive deals with new plants, also assumptions had to be made concerning new plants. Due to a lack of data on this issue some assumptions had to be made:
- for the power sector data of (Jankowski, 1998, p. 37) were used;
- for the industrial sector it has been simply assumed that by the year 2010 50% of the existing plants will be replaced by new plants, or will be modernised (with a gradual implementation between 2000 and 2010). By 2015 75% is assumed to be “new”. This implicates that these plants have to comply with the requirements for new plants of the directive.

For new sources concentrations of pollutants in the flue gas are estimated and compared with the requirements of the directive to determine the needed emission reduction.

For existing sources the allowed amount of emissions to comply with the directive has been estimated. By comparing the emissions of existing sources in case no reduction would take place with the allowed amount of emissions, the (eventual) needed emission reduction is calculated. Next it is assumed that each source would be required to reduce emissions with the same percentage.

Following that, for each source a 'marginal cost function' was added, based on technological options. Basically these functions describe the marginal costs of reducing one unit of emissions. The unit costs (expressed in € per kg reduced emission) for each of the technologies are stored in the MOSES database.

By multiplying emission reduction by unit costs (and investments) the total costs and investments are calculated for each source.

For as well existing as new sources the total investments and annual costs in 2000, 2005 and 2010 have been calculated and compared with the costs in 1996. The approximation costs and investments are then calculated by subtracting the investments and costs in 1996.

The next sections will describe the data used and the results obtained.

5.3.2 Emissions

Emission data for 1980 and 1996 were obtained from various sources:
- power plants (Berbeka, 1998), (Jankowski, 1998);
- industrial plants (ARE S.A., 1997c), (Ministry of Environment, 1998).

As an example some data on sources in Poland on thermal capacity, fuel input, emissions and emission factors for the power sector are summarised in the table below.

Table 5: Thermal capacity, fuel input, emissions and emission factors for the power sector in Poland

Plant	Fuel	capa city	fuel input		SO2				NOx				particles		
			coal	HFO	emission-factors		emissions		emission-factors		emissions		Emiss. factors	emissions	
					initial	current	initial	current	initial	current	initial	current	initial	initial	current
		MWth		kton/y	mg/m3	mg/m3	kton/y	kton/y	mg/m3	mg/m3	kton/y	kton/y	mg/m3	kton/y	kton/y
Total		94953						1191				375.4			156.2
A LSP	bc	11880	34446	16	2959	2071	326.3	228.4	628	377	69.2	41.5	28953	3192.4	9.3
B1 DRY	bc	1200	8549	19	1935	1935	102.5	102.5	451	271	23.9	14.3	11235	595.3	9.2
B2, FBC	bc	2400													
C1	bc	1810	4774	19	1935	1935	16.5	16.5	937	937	8.0	8.0	45007	384.6	2.4
D1, LSP	bc	2045	4441		1935	1935	48.7	48.7	493	296	12.4	7.4	11847	298.0	6.1
D2, CCGP	bc	600							420	420	1.5	1.5			
E1, DRY	bc	1650	10560	13	2977	1935	168.9	109.8	517	310	29.3	17.6	32282	1830.9	21.8
E2, FCB	bc	3795													
F1, DSP	hc	2796	3921	7	1653	1653	54.8	54.8	916	916	30.4	30.4	23883	791.6	3.0
F2, FBC	hc	4473													
G1	hc	4528	3149	12	1934	1934	57.8	57.8	1113	668	33.3	20.0	20906	625.3	2.0
H1	hc	436	243	2	3103	3103	2.6	2.6	2113	2113	1.8	1.8	40604	34.3	0.4
I	hc	688	352		2501	2501	6.2	6.2	1019	1019	2.5	2.5	31868	79.2	0.7
J	hc	4656	3526	6	2501	2501	75.1	75.1	842	505	25.3	15.2	25694	771.6	7.4
K, DRY	hc	4672	4096	14	2268	1474	83.9	54.5	1023	614	37.8	22.7	23558	871.3	11.6
L1,1	hc	412	258	10	2500	2500	6.8	6.8	829	498	2.3	1.4	21118	57.7	3.7
Etcetera															

source: based on (Berbeka, 1998); (ARE, 1997a); (ARE, 1997b) and estimations
explanations:

- MWth: Mega Watt thermal capacity;
- hc = hard coal; bc = brown coal; o = heavy fuel oil;
- initial emissions = emissions before abatement; current emissions = emissions (eventually after abatement) in the year of reporting;
- LSP = limestone scrubbing process; DSP = dry sorption process; DRY = dry additive injection; FBC = fluidised bed combustion; CCGP = combined cycle gas plant.

For the industrial sector it was impossible to obtain sufficient data on large combustion plants to enable simulations at plant level. In the reviewed sources (Min of Environment, 1998a) (ARE, 1997c), essential data were lacking (either emissions, emission factors, division of emissions over various capacities at plant level; fuel use). The approach therefore has been as follows:

- from (Min of Environment, 1998) the total emissions of SO_2 and NO_x for the most polluting plants in Poland have been calculated at the sectoral level;
- from (ARE, 1997c) the division of capacity over various classes – per fuel type – at the sectoral level has been determined. This division has been used to estimate sectoral emissions at the various capacities. Gradual attention has been given to emission factors for SO_2 (natural gas has no SO_2-emissions, Heavy Fuel Oil has a high factor).

This has resulted in estimates of emissions of SO_2 and NO_x at sectoral level (for various capacities and types of fuel). Total SO_2 emissions in industrial large combustion plants were estimated at 150 kton, NO_x emissions at 64 kton (1996). The emissions were divided over 34 sources.

5.3.3 Development of emissions

For the emission projections a time horizon of 2020 has been taken. For the projection of emissions energy scenarios have been used, for brown coal fired power plants individual estimates were available (Jankowski, 1998), for the hard coal fuelled plants the general energy-projection has been used.

5.3.4 Unit costs

The following table gives a partial example of a MOSES database for SO_2. Similar databases are used for NOx and particles.

Table 6: Partial MOSES Database for SO_2

Description	marginal emission reduction	unit cost €/kg	Unit investment €/kg
Reduction SO2-emissions, limestone addition fluidised bed combustion coal, 250 MWi	70.0%	0.52	1.03
Reduction SO2-emissions, limestone addition fluidised bed combustion coal, 25 MWi	70.0%	0.74	1.23
Reduction SO2-emissions, limestone addition fluidised bed combustion coal, 5 MWi	70.0%	0.79	1.17
Dry additive injection, 350Mwe	35.0%	0.14	0.19
Dry additive injection, 250Mwe	35.0%	0.14	0.23
Dry additive injection, 150Mwe	35.0%	0.14	0.30
Dry additive injection, 50Mwe	35.0%	0.17	0.68
Dry sorption process, 350MWe, after DAP	61.5%	0.24	3.31
Dry sorption process, 250MWe, after DAP	61.5%	0.25	3.44
Dry sorption process, 150MWe, after DAP	61.5%	0.28	3.84
Dry sorption process, 50MWe, after DAP	61.5%	0.31	4.17
Limestone scrubbing process, 350MWe, after DAP/DSP	80.0%	0.90	6.08
Limestone scrubbing process, 250MWe, after DAP/DSP	80.0%	1.09	8.57
Limestone scrubbing process, 150MWe, after DAP/DSP	80.0%	1.32	11.77
Limestone scrubbing process, 50MWe, after DAP/DSP	80.0%	1.58	15.28

source: TME, 1997, based on various sources (ESC, 1988) (IIASA, 1996) (Jankowski, 1998)

5.4 Costs and investments of approximation

To estimate the costs and investments of approximation various simulations have been carried out.

First, simulations in which it is assumed that only source-specific reduction targets (at plant level) are valid. This is the basic simulation to determine whether these targets also fulfil the general needed emission reduction to comply with the emission ceiling of the second sulphur protocol.

If the basic simulation shows that additional emission-reduction is needed two types of simulations have been carried out afterwards, both aiming at reaching the overall emission-target:

- a simulation in which it is assumed that additional emission reduction will be achieved by setting a general standard for sources that are not regulated in the basic simulation. This implies that already existing standards prevail, but additionally a general reduction target is set for other sources (or already regulated sources, if the source specific target is less than the general target);
- a simulation in which by means of a market based approach – for example increased emission charges or marketable permits – the general emission reduction is achieved. In MOSES this is simulated by varying the emission tax level, till the final emissions are equal to (or slightly under) the emission ceilings. In this simulation a restriction has been built-in: the already specified source specific targets (standards) should be respected. Additional emission reduction should be achieved by using charges or tradable permits.

Basic simulations (source specific reduction targets)
In the following table the results of the basic simulation are presented for SO2, NOx and particles.

Table 7: Emission-ceilings, final emissions, annual costs and investments for reduction of SO2, NOx and particles, assuming source specific standards, 1996-2000-2005-2010

		1996	2000	2005	2010
SO2					
Ceiling	kton		1363	1146	735
final emissions	kton	1344	1090	1060	1079
Investments	mln €	1788	2797	3393	3454
annual costs	mln €	376	566	668	708
Nox					
Ceiling	kton		438	368	236
final emissions	kton	454	473	490	475
Investments	mln €	50	120	150	171
annual costs	mln €	8	19	24	28
Particles					
final emissions	kton	157	172	116	116
Investments	mln €	1 664	1 832	2 176	2 139
annual costs	mln €	433	477	578	568

The table shows that application of source specific standards are not enough to comply with the national emission ceilings for SO_2 (2010) and NO_x (2005, 2010).

Additional emission reduction simulations
To comply with the requirements of the directive and the second sulphur protocol additional emission reduction is required for SO_2 and NO_x. The results of the simulations are presented in the next table.

Table 8: Final emissions, annual costs and investments for reduction of SO_2 and NO_x, assuming source specific standards and a tradable permits or pollution charges (market based approach) or a general reduction target (regulatory approach), 2010

SO2		Market based approach (charge rate of 0.45 €/kg)	Regulatory approach
Final emissions	Kton	630	630
Annual costs	Million €	846	874
Investments (1996-2010)	Million €	4 339	4 256
Nox		(charge rate of 0.43 €/kg)	
Final emissions	kton	212	212
Annual costs	Million €	98	143
Investments (1996-2010)	Million €	337	563
TOTAL			
Annual costs	Million €	944	1017
Investments (1996-2010)	Million €	4 676	4 819

The table shows that a market-based approach can reduce costs and investments, especially in the case of NO_x emission reduction.

5.5 Conclusions, priorities and recommendations

Based on relatively rough data on polluting sources the total investments of approximation for this directive are estimated at € 3.3 to 3.4 billion. This number may be 10-20% higher because not all industrial sources could be included in the analyses, due to the lack of sufficient detailed data on these sources.

A "least cost strategy" may lead to significant cost-savings as some preliminary simulations show. For SO_2 the maximal saving is estimated at 8%, for NO_x it might be up to 45%.
More detailed cost-functions and inclusion of all sources in industry may lead to better estimates and probably higher estimated cost-savings.

6 EU PRIORITY ENVIRONMENTAL PROBLEMS: FINE PARTICLES

This chapter is based on work carried out for the RIVM in the framework of the Economic Assessment of Priority European Environmental Problems (PEEP) and was mainly written by Coen Sedee.

6.1 Introduction

This chapter gives the results of the project "Abatement costs of fine dust in European countries", carried out by the Institute of Applied Environmental Economics (TME) in commission of the RIVM. The overall objective of the project was to draft cost functions of abatement measures on country-level for fine dust (PM10) and to assess costs of different abatement strategies.

In section 2 the different preparation steps to make the available fine dust data suitable to be applied in the simulation model MOSES (Model On Sustainable Environmental economic Scenarios) are summarised. In section 3 the results of different simulation scenarios are reported.

6.2 Data preparation

Cost-effectiveness curves (or marginal cost functions) and total abatement costs are calculated with MOSES. Below, all elements of cost calculation will be separately described, focusing on starting points, data requirements, problems and assumptions to solve these problems.

6.2.1 Fine dust emission database

Calculations on the abatement costs for fine dust emissions are carried out on the basis of TNO emission data (TNO 1997). These data are divided in (i) emissions from mobile and stationary sources and (ii) combustion and non-combustion emissions. Also a distinction has been made between Eastern and Western European.

In this study calculations have been carried out for 24 European countries (EU excluding Netherlands, 10 CEE countries).

Specific energy growth figures from IIASA (IIASA 1998) have been used to estimate the specific sectoral growth of emissions for the period 1990-2010.

6.2.2 Abatement technology database

Based on (TNO 1997) with additional information from (Turner) and (CE) a database was created including for each source type various (marginal) abatement technologies, like:

- Cyclones;
- Electrostatic precipitator (ESP);
- Fabric filter (FF);

The main features of this PM10 abatement database are:

- costs are given in guilders (prices 1990) per kilogram emission abated;
- costs express the Dutch cost level. In cost calculations with MOSES other cost factors can be specified in order to simulate country-specific cost levels;
- the technology database gives for each technology its purification efficiency and unit exploitation costs, which are based on unit investment costs (construction and equipment) and unit operational costs (labour, energy and other);

- in case of application of more than one abatement technology for the same emission source, costs and purification efficiency of the next technique are specified marginally in relation to the foregoing technique.

6.2.3 Emission targets and policy scenarios

In the cost calculations in this study, emission targets should be based on all relevant EU Directives issued before the second half of 1997. Regarding these directives and the emission targets to derive, two difficulties arise:
(i) different directives refer to different levels of regulation and
(ii) translation of the reduction goals specified in those directives can be a problem as the emission data available are too aggregated to combine with relevant reduction goals.

These problems can be illustrated by the description of the EU Directives that are relevant in this respect:

- 96/62/CE, concerning Ambient Air Quality;
- 88/609/CE, concerning dust emission limit values for new large combustion plants;
- 96/61/CE, concerning Integrated Prevention and Pollution Control.

EU directive on Ambient Air Quality 96/62/CE states that for the end of 1996 proposals for limit values are stated by the member states. These values indicate air quality standards which are difficult to translate to general emission reduction targets applicable to an emission source irrespective of its location.

EU directive 88/609/CE gives dust emission limit values for new large combustion plants, expressed in maximum concentrations in flue gasses. To use these limits, information is required of (average) current concentrations of fine dust in flue gasses per (sub)sector. However, the TNO data gives total absolute emissions per emission source.

EU directive 96/61/CE on Integrated Prevention and Pollution Control contains a number of general rules stating among others that best available technology has to be used. These guidelines are too imprecise and general to be translated into emission reduction targets.

Only time-consuming and costly investigations could cope with the above mentioned problems. Therefore, the cost calculations presented below do not give results for EU reduction targets. Instead, simulations were carried out for the following policy scenarios:

- standard abatement 1990 and 2010 (“baseline”). In this scenario current (1990) emission reduction targets at source level have been applied also to 2010;
- maximal abatement. In this scenario maximal abatement is assumed for all sources;
- optimal abatement. In this scenario 3 simulations have been made for the application of “market based incentives”, allowing respectively measures cheaper than 0.15 €/kg, 1 €/kg and 5 €/kg (on top of measures already taken in the “baseline”).

The simulations are thus expected to cover the whole range of abatement opportunities, enabling a comparison of total abatement costs and resulting emission-reduction.

6.3 Results

In conformity with RIVM, simulations have been carried out for 24 European countries namely: the actual 15 European Union countries (with the exception of The Netherlands) and 10 countries that at “short” notice will join the EU. These 10 countries are: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovak Republic and Slovenia. As stated in section

2.3 no results for EU reduction targets could be presented. In the next sections the results of three simulation scenario's are presented:

1. Standard abatement: the level of abatement in 1990 has been maintained for 2010;
2. Maximal abatement: all available abatement technologies have been applied in 2010;
3. Optimal abatement: starting with the standard abatement, the abatement technologies cheaper than the chosen emission taxes are taken from the abatement technology database.

6.3.1 Total standard abatement (costs) for 1990 and 2010

In table 1 the total emissions (after abatement), reduction (efficiencies) and abatement costs are presented for the years 1990 and 2010 respectively for the "baseline" scenario.

Table 9: Emissions, emission reductions and abatement costs for 24 European countries in 1990

Country	emissions kton/year		reduction (%)		abatement costs, € mln/year	
	1990	2010	1990	2010	1990	2010
CEE-10	2110	2517	78,3	76,8	1006	1106
EU-14	2825	3268	90,8	89,0	3936	3907
EUROPE 24	4935	5785	87,8	85,7	4942	5013
Austria	38	42	97,0	96,9	345	388
Belgium	65	63	95,2	95,1	133	129
Bulgaria	187	288	77,3	69,9	83	84
Czech Republic	239	249	81,7	80,5	107	106
Denmark	51	69	91,1	83,8	110	98
Estonia	40	54	72,2	64,7	21	19
Finland	47	56	88,4	89,9	57	64
France	397	605	89,1	83,0	737	721
Germany	1322	1352	84,3	82,7	887	854
Greece	55	72	96,4	95,5	116	119
Hungary	137	163	80,3	77,9	122	122
Ireland	31	36	87,0	89,6	36	41
Italy	295	312	93,5	92,8	517	510
Latvia	68	80	72,2	68,9	35	35
Lithuania	94	177	72,2	59,7	48	56
Luxembourg	6	5	97,2	97,3	7	7
Poland	923	1038	73,4	74,7	313	397
Portugal	31	45	94,9	93,3	44	47
Romania	258	306	85,8	85,1	208	219
Slovak Republic	136	136	81,7	80,9	61	60
Slovenia	26	25	81,6	81,3	9	9
Spain	171	203	95,1	94,1	379	380
Sweden	42	48	91,0	90,7	66	70
United Kingdom	274	360	93,1	90,0	502	478

Comparing the columns for 1990 and 2010 shows that the emission reduction in 2010 is (as expected) more or less the same as in 1990. Exceptions are the countries Bulgaria, Denmark, Estonia, France, Lithuania and the United Kingdom. In all these countries the emission reduction in 2010 is considerably lower than in 1990. This is caused by the different emission growth rates: if the industry sector without emission abatement in 1990 grows harder than the one with emission abatement in 1990, this results in an overall lower emission reduction in 2010. This is often accompanied with lower abatement costs in 2010. With the exception of the countries Finland, Ireland, Luxembourg and Poland the emission reduction in 1990 is higher than in 2010 meaning that sectors with unabated emissions grow faster than the ones with emission abatement in 1990.

6.3.2 Total maximal abatement (costs) for 2010

In table 2 the total maximal abatement (reduction and costs) for 2010 are presented. This means that all the available abatement technologies have been applied to sources in the various sectors.

Table 10: Initial emissions, final emissions, maximal emission reductions and maximal abatement costs for 24 European countries in 2010

Country	initial emissions kton/year	final emissions, kton/year	reduction %	abatement costs € mln/year
CEE-10	10825	316	97,1	12664
EU-14	29697	1103	96,3	32105
EUROPE 24	40522	1419	96,5	44769

Comparing table 2 with table 1 it can be seen that maximal reduction of PM10 emissions would require almost 10 times more financial funds than continuation of the current policy. By applying maximal abatement, emissions in CEE-10 could be reduced from 2517 kton per year to 316 kton per year (in 2010), in EU-14 from 3266 kton to 1103 kton.
The overall emission reduction in Europe (24) would increase from 85.7% to 96.5%.

6.3.3 Total optimal abatement (costs) for 2010

In the table 3 the optimal abatement (reduction and costs) is presented for three different cases:
1. allowed maximal marginal abatement costs < 0.15 €/kg;
2. allowed maximal marginal abatement costs < 1 €/kg;
3. allowed maximal marginal abatement costs < 5 €/kg.

The situations as described in these three cases could be achieved by applying Market Based Incentives, like an emission tax (with the rates as stated above) or a programme of tradable permits.

Table 11: Emission reductions and abatement costs for 24 European countries in 2010 at maximal marginal costs of respectively 0.15 €/kg, 1.00 €/kg and 5.00 €/kg

Country	marginal costs<0.15 €/kg		marginal costs<1 €/kg		marginal costs<5 €/kg	
	reduction %	abatement costs € mln/year	reduction %	abatement costs € mln/year	reduction %	abatement costs € mln/year
CEE-10	91,3	1226	94,7	1381	95,6	1595
EU-14	91,9	3946	94,2	4190	94,9	4618
EUROPE 24	91,8	5172	94,3	5571	95,0	6212

The simulations for these three scenarios show the following:
- Allowing all measures cheaper than € 0.15/kg only a slight increase in total costs (Europe 24) would result, whereas emissions could be reduced substantially compared to the baseline scenario (table 1). Annual costs would increase by only 3%, whereas overall emission reduction would be 91.8% (compared to 85.7% in the baseline);

- If measure up to € 1/kg are allowed, overall emission reduction would be 94.3%, the annual costs (Europe 24) would increase by 11% (compared to the baseline, table 1);
- Almost the same emission reduction as in the "maximal scenario" (table 2) can be achieved if measures up to € 5/kg are allowed. In this case annual costs would be 24% higher than in the baseline scenario. On the other hand, if the total annual costs are compared with the "maximal scenario" these would be only 14% of maximal abatement costs (table 2).

The overall conclusion from this "optimal scenario" can be that a cost-effective and cost-efficient approach could save enormous amounts of money at hardly any "cost" for the environment. Here, once again it is shown that a market based approach can give considerable financial advantages without harming the environment.

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APPENDIX1 OVERVIEW OF PROJECTS CARRIED OUT WITH MOSES

The following table gives an overview of the projects carried out with MOSES so far.

year	study for	countries	coverage	short description
1992	Worldbank	Brazil	COD, Ptot, Ntot	scenarios for sewage treatment (all states) scenarios for industrial waste water reduction (3 states)
1992-1994	EU (DGXI)	Germany, France, United Kingdom, Italy, Spain, Netherlands	SO2, NOx, VOC COD, Ptot, Ntot	scenarios for reduction of emissions in EU (air: large sources; water: urban waste water treatment)
1992	Polish Ministry of Environment	Poland	SO2, NOx, PMT COD, Ptot, Ntot waste	three scenarios for emission reduction strategies
1993-1994	Worldbank	Mexico	SO2, NOx, VOC COD, Ptot, Ntot	cost-effectiveness of air pollution control optimising revenues for waste water treatment
1993-1994	Flanders Government	Flanders	COD, P-tot, N-tot, heavy metals	Industrial waste water, regulatory and cost-effective scenario
1996-1999	RIVM (EU DGXI)	EU-15 CEE	PMT COD, Ptot, Ntot waste	cost-assessment for various scenarios in EU and CEE
1996-1997	Ministry of Environment NL	Netherlands	SO2, NOx	estimation of cost advantage of tradable permits for acidification targets 2010, large sources
1996-1997	Phare	Slovakia	SO2, NOx, PMT COD, Ptot, Ntot waste	revenue estimate of emission charges/taxes
1997	RIVM	Netherlands	SO2, NOx	estimation of maximal tax revenues in 2010, if eco-taxes on SO2 and NOx are introduced
1997-1998	Phare	Lithuania	SO2, NOx, PMT, VOC COD, Ptot, Ntot waste	cost assessment of implementation of EU directives, incl. “least cost” assessment
1997-1998	Phare-DISAE	Poland	SO2, NOx, PMT COD, Ptot, Ntot waste	cost assessment of implementation of EU directives, incl. “least cost” assessment
1997-1998	Phare DISAE	Estonia	SO2, NOx, PMT COD, Ptot, Ntot waste	cost assessment of implementation of EU directives, incl. “least cost” assessment
1998-1999	Ministry of Environment Latvia	Latvia	SO2, NOx, PMT COD, Ptot, Ntot waste	cost assessment of implementation of EU directives, incl. “least cost” assessment
1998-1999	Worldbank	Ukraine	SO2, NOx, PMT	cost assessment of implementation of EU directives, incl. “least cost” assessment