SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY

Intermediary report - January 2003

MULTI-POLLUTANT EMISSION REDUCTION POLICIES
CP-25

VITO – IW –BIM/IBGE - VMM

SPSD II

PART 1

SUSTAINABLE PRODUCTION AND CONSUMPTION PATTERNS

- GENERAL ISSUES
- AGRO-FOOD
- ENERGY
- TRANSPORT

This research project is realised within the framework of the Scientific support plan for a sustainable development policy (SPSD II)

Part I "Sustainable production and consumption patterns"

The appendixes to this report are available at :
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Multi-pollutant emission reduction policies

Multipol project

DWTC/SSTC network code NR CP-67-251

Intermediary scientific report

Prepared by Vito

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1 Introduction

1.1 Context and summary

Under impulse of several recent or ongoing international agreements (Kyoto protocol, EC directives, Gothenburg protocol), European and other countries will have to make serious efforts to reduce air pollutants. Today, national emission ceilings are (or will be) fixed for various pollutants which have to be met within a decade. In order to preserve the highest welfare levels for the community these ceilings have to be realised in a cost efficient way.

So far, only one-pollutant abatement techniques are evaluated to meet the future environmental restrictions. It is obvious that one-pollutant analyses are not exhaustive and therefore do not guarantee the highest welfare levels. Due to complexity reasons, multi-pollutant analyses are not yet widespread. Though, maximum cost efficiency can be realised only through the integrated assessment of multi-pollutant abatement technologies.

Besides the choice of abatement technologies, also the selection of the appropriate policy instrument (sectoral agreements, tariffs, emission trading, regulation) may have great influence on the global cost efficiency. Namely, different policy instruments distribute environmental costs in a different way among citizens, companies and government and will generate different welfare aspects. On the basis of these welfare aspects, the optimal policy instrument can be selected.

1.2 Objectives

The final objective of the project is to develop the tools (optimisation and simulation software tools) that enables the integrated assessment of multi-pollutant technologies and can evaluate the benefits of multi-pollutant policies in the Belgian political context. The optimisation tool will be used to derive single and multi-pollutant cost curves at sectoral/ regional or at the national level and to define the physical limitations. The simulation tool will be used to investigate the benefits of different policy instruments and to derive practical considerations for real policy.

1.3 Expected outcomes

The tools will be used to support Belgian policy makers. For this purpose different policy scenario's will be developed, either on own initiative and on request by federal or regional authorities. Scientific conclusions will be derived and published internationally.

2 Detailed description of the scientific methodology.

The global approach of the project is basically bottom-up. Large amounts of data have to be colleted, verified, and stored in an appropriate database format. Treating huge amounts of data has important practical considerations. Therefore the design of an appropriate database format is crucial for the realisation of the project. For the optimisation and simulation tools, several hundreds lines of program code will have to be written and tested.
In order to build experience in this area, Vito has realised some sectoral emissions reduction potential studies. These studies are ordered and funded by the Flemish environmental authorities. In these studies, emission reduction cost curves are derived for different non-GHG pollutants and multi-pollutant cost reduction analysis is done as well. Actually multi-pollutant emission reduction studies have been done for the Flemish electricity sector, and for iron and steel production. Early 2003 an additional study for the chemical industry starts. Some results of these studies are illustrated in the next section.
These studies contribute to a large extend to the success of the project for several reasons:

- They allow to gain additional experience in this area and this will help to define modelling requirements, to define data requirements and appropriate database formats.
- It is investigated whether existing modelling tools can be used to derive emission reduction cost curves and to perform multi-pollutant reduction cost analysis. In the sectoral studies, the original Markal modelling tools and model code are used for this purpose.
- The users committees from these studies guarantees the quality and reference results are produced.
- Additional funding for these studies is provided by the Flemish authorities.

If data collection and model building in the first sectoral studies have been done manually (taking emissions figures from paper), early 2003 we will start the automatisation process of data collection in the sectoral study for the chemical sector using an existing database at the VMM.

Then gradually we will continue to develop and improve the system for automatic modelling generation.

3 Detailed description of the intermediary results, preliminary conclusions and recommendations.

3.1 Experiences from sectoral studies

In the sectoral studies the Markal modelling tools have been used to derive marginal abatement cost functions for different pollutants and to do multiple pollutant abatement cost analysis. From these exercises, a lot of experience was gained in the different fields and tasks related to the modelling work: What are the data requirements? Which data are available? How to model the different processes? How much modelling detail is required?

Sectoral models have been built enabling to evaluate different kind of emission reduction options:

- by retrofitting existing installations with new end-of pipe techniques or primary measures
- by changing fuels in existing installations
- by changing the load factors of different installations
- by investing in new installations and closing old equipment

Shadow prices on emission constraints are interpreted as marginal abatement costs. The derivation of marginal emissions reduction cost functions is based on stepwise sharpen emission ceilings.

For these exercises, the original Markal code has not been changed. However, additional utilities to derive cost functions have been programmed based on VBA in Excel.

3.1.1 Experiences from the electricity sector

A detailed model has been build for the whole sector. Figure 1 demonstrates the model structure, including retrofit options for a typical coal/gas fired plant. The model uses similar structures for other types of electricity plants.

Modelling retrofit options in Markal.

The typical historical horizon for the Markal-Model is 30 to 50 years. Moreover, the Markal software has been built to deal with GHG's. The objective of the multipol project is to answer questions in a 5 to 15 years horizon. From a modelling point of view a fundamental difference is the existence of retrofit options for non GHG's pollutants.

In Markal lineair programming is applied and capacities and activities are defined continuously. To understand the problem it is necessary to understand the difference between continuously and discrete modelling. If discrete modelling is applied, capacity units are defined as are installed with a given capacity. If we take the example of an electricity plant, an investment option could be to install a 400 Mw STEG electricity plant or an integer multiple of this (800Mw, 1200 Mw). However, in Markal investment is defined on a continuous basis, meaning that a 290 MW or a 455 MW investment is possible as well as this is the amount required by electricity demand. In Markal, investment costs are defined on a per unit basis.

The Markal approach poses one particular problem when dealing with retrofit. If for instance, some installation is used for 60 % of time, then a retrofit flue gas cleaning installation will be used for 60 % of time as well. However, if this retrofit option is introduced as a standard process in Markal, then the capacity installed will only be 60 % of the nominal capacity required and utilisation will be 100 % over time. This means that investment and fixed operating costs are underestimated for 40 %.

If an installation runs at full capacity, then this problem is not relevant. Otherwise if the activity rate is known, then a correct cost evaluation is possible by increasing unit investment costs. If the activity is not known, or (even worse) if the activity rate is endogenous determined in the optimalisation then the problems become relevant. The latter case is typical for the electricity sector. For instance, one option to reduce emissions could be to reduce activities of coal fired plants in favour of gas fired plants. However, if stronger reductions are required, capacities of gas-fired plants might not be sufficient and end-of pipe measures on coal fired plants will be the only option. In this case, coal fired plants should be used again at 100 %.

One solution to this problem is to introduce Mixed Integer Programming options in Markal. Mixed integer variables could be used to define retrofit units and contnuous variables could be used for standard per unit modelling. One major disadvantage of this approach is that shadow-prices do not represent marginal reduction costs. Some additional work should be done to derive marginal costs.

The approach we have followed so far is illustrated in Figure 2. In an iterative loop, the retrofit investment costs are adapted (by lowering or increasing the availability factor) so as to represent the real utilisation of the electricity plant. This loop continues until convergence is achieved. In 90 to 95 % of the evaluation points, a global minimum was found within 8 iterations. In 5 to 10 % the system converged to a local minimum, and not to the global in less than 9 iterations. In these cases, a manual intervention was needed.

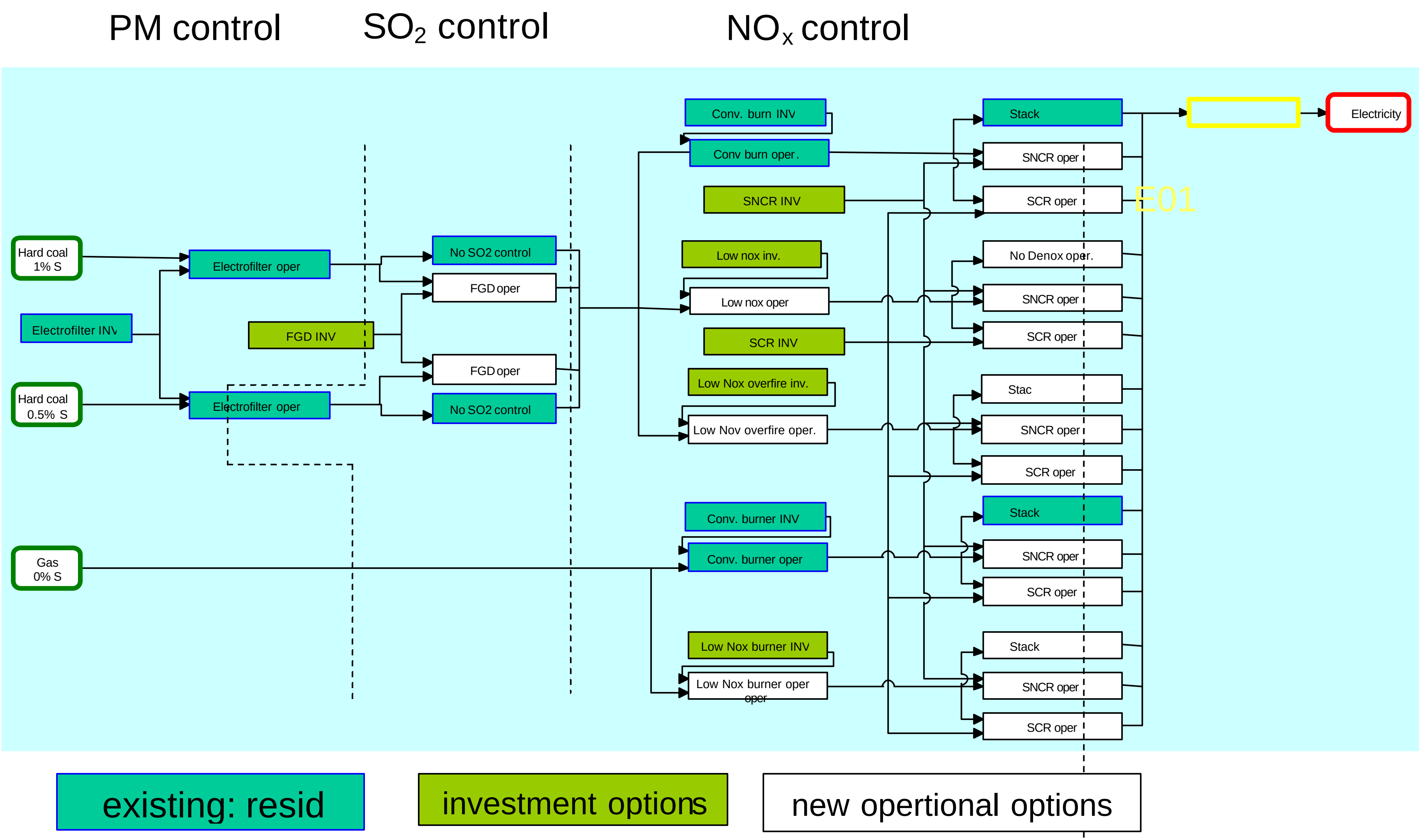

Figure 1: Typical Markal structure for a coal/gas fired plan in the sectoral study

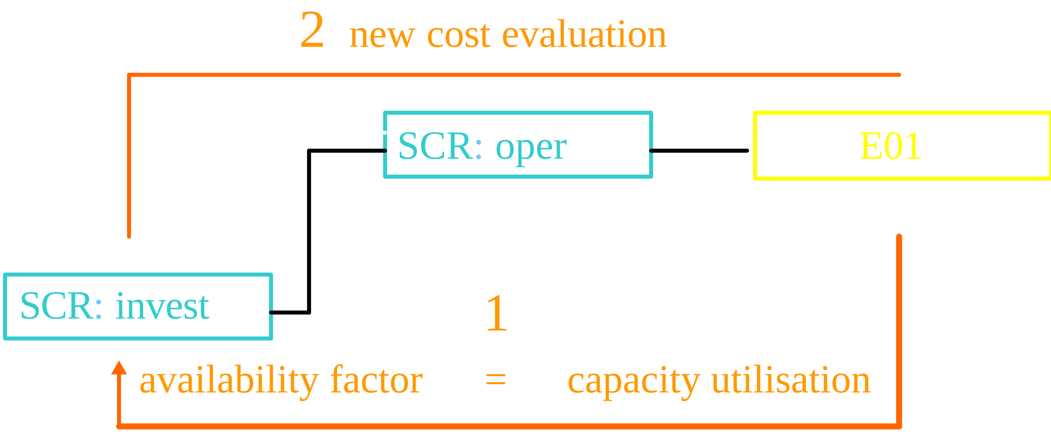

Figure 2: iterative structure for dimensioning retrofit options in the electricity sector.

Marginal emission reduction cost curves (Single pollutant cost evaluation).

Marginal abatement cost functions have been derived in different scenarios. One marginal cost curve requires between 150 and 250 Markal runs. Computer time is about 3 hours. Some results are demonstrated in Figure 3. Scales are omitted in the figure for confidentiality reasons.

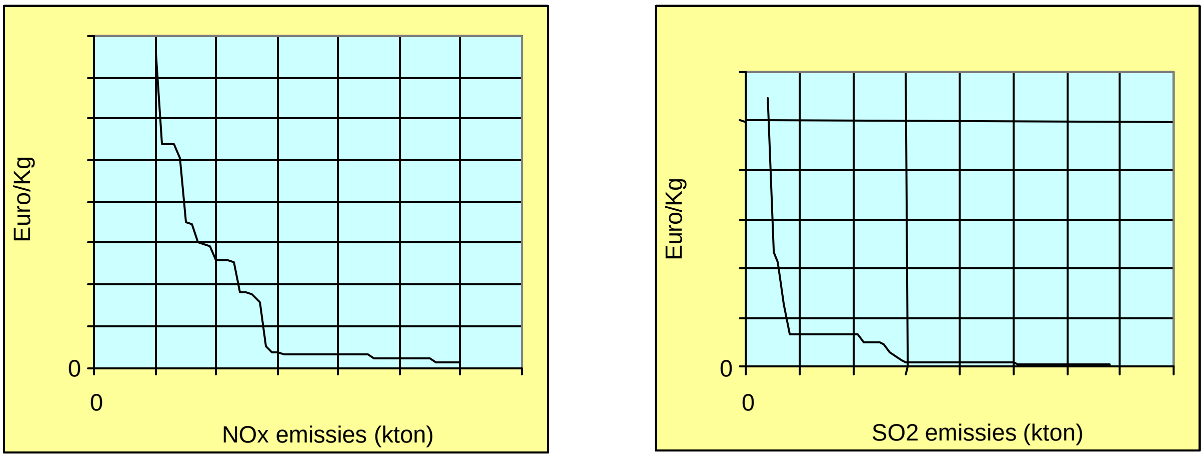

Figure 3: Marginal abatement cost functions for NO_x and SO_2

Multiple pollutant cost evaluation experience.

Using the same approach, joint reduction of NOx and SO_2 emissions exercises have been done. Some additional problems to find valid solutions have been encountered. annual intervention, to exc lude certain options, was necessary. In general we can say that the iterative procedure gives more problems when joint emission reduction exercises have been done. The typical problem is that certain options will not be selected at the full 100%. In these cases, these options have been excluded.
Regarding cost-evaluation total emissions reduction costs appear to be between 4% and 28% below the sum of the costs in the cost curves.
Table 1 gives some results for different targets and different scenarios, relative to the costs of the NEC target in the reference scenario. It appears from these results that a high gas price has a very significant impact on the emission reduction costs. On the other hand, it seems that the ratification of the Kyoto protocol is favourable for the reduction of NO_x and SO_2. It must be mentioned that the cost evaluation in the Kyoto scenario does not include the cost of the Kyoto scenario itself.

Table 1: Evaluation of the total emission reduction costs for NOx and SO2 abatement in different scenarios.

	NOx(kton)	SO2(kton)	Cost
NEC target	16	5,9	
Reference	16	5,9	XX M€
High gasprice	16	5,9	+ 15 %
Kyoto	14,32 nb	5.9	-83 %
NEC+ target	10,87	4,32	
Reference	10,87	4,32	+ 60%
High gasprice	10,5 nb	4.32	+ 150%
Kyoto	10,87	3,94 nb	- 36%

3.1.2 Experience from Iron & Steel production

A similar approach has been used for the Iron & Steel producing industries.
The sector exists of one integrated oxygen steel factory (Sidmar) and one stainless steel factory (ALZ). Major emissions sources are the coke plant (for NOX) and two sinter plants (for NOX and SO2) at Sidmar. As load factors are constant (the company is assumed to produce at full capacity) the problem illustrated in figure 2 is not relevant

here. Consequently, the derivation of marginal cost abatement functions is rather straightforward. However, we have encountered problems in multiple pollutant abatement evaluations. When imposing emissions ceilings for two pollutants (SO2 and NOX), it happens that reduction technologies are selected partially, which is a non realistic outcome. Contrary to the experiences of the electricity sector, it was difficult to solve these anomalies by manual intervention[1].

3.1.3 Marginal cost curves and ceiling cost-curves.

The additional cost to reduce emissions by one unity is expressed in marginal abatement cost functions. They can be expressed at installation level, at sectoral level or aggregated to national level. Abatement techniques are ranked by increasing marginal costs. Marginal cost functions give the cheapest solution to reduce emissions up to a certain level. If marginal cost functions are based on discrete techniques they are not continuously defined.

Ceiling cost curves are interesting form a companies point of view. Ceiling cost curves give the cheapest solutions for a company to fulfil an emission ceiling. So contrary to marginal abatement functions the accent in more on the emission level. If emission abatement options are continuously defined (such as fuel substitution in a bi-fuel installation) then ceiling cost curves are identical to the marginal abatement functions. If abatement options are not continuously defined, then ceiling cost curves gives more intermediary solutions.

A small Gams program has been made to derive NOx and SO2 ceiling cost curves for the Flemish iron & steel sector, using mixed integer programming (MIP) facilities. Figure 4 illustrates the NOx ceiling cost curve. The marginal cost abatement solutions are indicated as well. One can see that the average abatement cost is decreasing for a ceiling between 8000 and 600 ton. Around 6000 ton, the ceiling and marginal cost curves give the same solutions (approx € 1,5 /ton). At the left hand side of the figure, the ceiling and the marginal cost curves are somewhat closer, although the ceiling cost curves gives more economically less efficient intermediate solutions.

One important disadvantage of the ceilings approach is that MIP does not give the marginal abatement costs. An attempt has been made to derive the marginal abatement costs from these results but this attempt was not successful. One obvious conclusion from this exercise is that ceilings can be highly inefficient, especially if they are not strong enough.

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[1] A similar problem has arisen for the electricity sector but there it was possible to get feasible results by excluding one or maximum two abatement options.

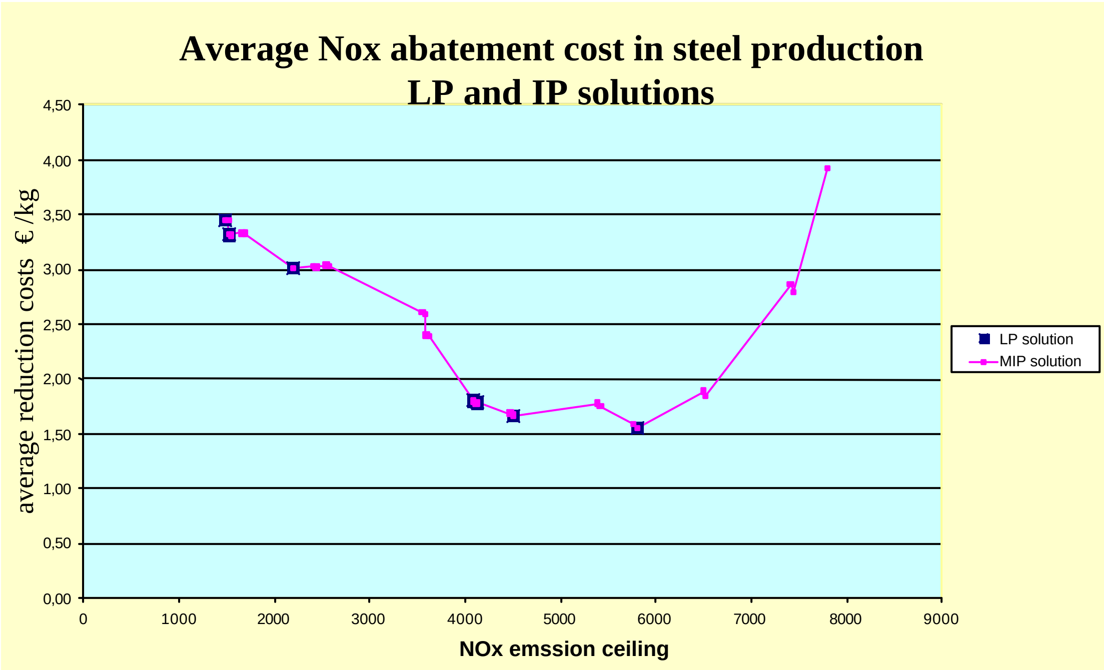

Figure 4: NOx Ceiling (MIP) cost curve for the Flemish Iron & Steel sector.

3.1.4 General conclusions for these sectoral studies.

In the sectoral studies we have experienced the benefits and pitfalls of a linear programming (LP) and of a mixed integer programming (MIP) approach.

Linear programming can be applied if abatement costs can be assumed to be continuously defined. Linear programming produces the marginal abatement cost functions. However two problems have been encountered. For the electricity sector it was found that the load factor for different installations was endogenous in the optimisation problem. For this reason an iterative procedure has been introduced. This iterative procedure is no guarantee for a global minimum. In approximately 5% of the evaluation points, the system converged to a local minimum and some manual intervention was needed. In multiple pollutant policy evaluation we have encountered problems in identifying feasible solutions.

Mixed integer programming is able to solve the two problems mentioned above. The iterative procedure is not required because the system will be designed to select only full capacities. As the assumption of continuously defined abatement options is released, only feasible solutions will be selected. However MIP will not produce the marginal abatement costs.

Therefore a new system should be able to use both LP and MIP programming.

3.2 Bibliographical researchon the knowlegde of ancillary benefits of a climat policy.

See annex 1

3.3 Compilation of emissions and technologies databases

In the Flanders region the VMM is uses de EIVR registration system for the registration of point emission sources. Walloon and Brussels use CollectER, the system provided by the European environment agency. Both systems collect data on emissions and energy consumption. A technical document describing the data availability in both systems and comparing actual availability with model requirements has been prepared.

In the next faze it will be investigated how the system can practically linked with a technology database and how additional production process information can be integrated.

Annex 1

Ancillary benefits and costs GHG gas mitigation