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Potentials and costs to reduce PM_{10} and $PM_{2.5}$ emissions from industrial sources in the Netherlands

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Preface

The project has been carried out from April 2001 to January 2002 for the Ministry of Housing, Spatial Planning and the Environment (VROM) and was commissioned by Novem. In addition, the work on the branch descriptions for appendix D has been conducted in the period February to August 2002. The project has been supervised by a Steering Committee that consisted of Mr. Klaas Krijgsheld (chair), Mr. Hans Kraaij (Ministry of VROM), Mr. Wilco van der Lans (Novem), Mrs. Elly Dejeu (Ministry of Economic Affairs / VROM), Mr. Winand Smeets and Mr. Kees Peek (RIVM).

The authors would like to thank all the members of the Steering Committee for their valuable discussions, contributions and cooperation.

The project has been conducted in the framework of the Netherlands Aerosol Programme (NAP) that has the aim to assess and to analyse the sources, mitigation policies and effects of Particulate Matter (PM) in the Netherlands in order to contribute to the evaluation in 2003 of the PM daughter directive in the European Union. The research programme runs from 2001 to 2003 and addresses all aspects of the PM source effect chain such as emissions, dispersion, air quality, epidemiology and toxicology. The programme has been instigated at the request of three Ministries, that of Housing, Spatial Planning and the Environment, that of Transport, Public Works and Water Management and that of Economic Affairs. The Netherlands Agency for Energy and the Environment (NOVEM) facilitates the execution of the research programme by the Netherlands Institute of Public Health and the Environment (RIVM, Bilthoven), the National Organisation for Applied Scientific Research (TNO, Apeldoorn), the Netherlands Energy Research Foundation (ECN, Petten) and the Institute for Risk Assessment Studies (IRAS, Utrecht).

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1. Introduction

1.1 Background

In the years 2005 and 2010 a European air quality target for PM_{10} with a yearly average value of 40 [1] and 20 [2] $\mu g/m^3$, respectively will be introduced, although a review of the Daughter Directive (1999/30/EC) of the EU Framework Directive on air quality (96/62/EC) is foreseen in 2003. Also, an additional target for $PM_{2.5}$ is under consideration. Air quality measurements in the Netherlands generally show rather high PM_{10} concentrations (about 40 $\mu g/m^3$ on an average) that could exceed the envisaged target values, especially in urban areas. In case of non-compliance with air quality standards the Netherlands might need to take action in order to improve air quality with respect to PM_{10}. Therefore, the potential and costs of measures for relevant sources in the Netherlands needs to be investigated. Besides PM_{10}, $PM_{2.5}$ emissions specifically might also need to be reduced as a consequence of future EU policy.

Most susceptible to national policy are the domestic emissions of primary PM_{10}, which are currently estimated to cause the ambient concentrations in the Netherlands for about 6% (see figure 1.1). Furthermore, the contribution of 11% by Dutch secondary aerosol (formed through atmospheric reaction of NO_x, SO_2 and NH_3) can also be influenced by national policy. It is assumed that the bulk of the domestic anthropogenic emission has been quantified with a reasonable accuracy. This does not apply to $PM_{2.5}$ for which no reliable inventory data exist yet.

The European air quality targets to be met might bring about the necessity to reduce domestic anthropogenic emissions of primary and secondary PM_{10} to a certain degree. An important contribution to total domestic emissions of primary PM_{10} in the Netherlands comes from industrial sources: one third (including energy industries) of the national total in 1998 (see figure 1.2). Another 5% stems from Commerce and Public services. These two sectors are subject of the study. Both sectors consist for a large part of large point sources and the expectation is that low-cost reduction options could be present. Also, the sectors can be addressed relatively easy by national policy, e.g. in contrast with the transport sector that is dominated by international technology and regulation.

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[1] With a daily average value of 50 $\mu g/m^3$, with a number of 35 permitted excursions per year.

[2] Indicative value, with 7 permitted excursions per year for a daily average of 50 $\mu g/m^3$.

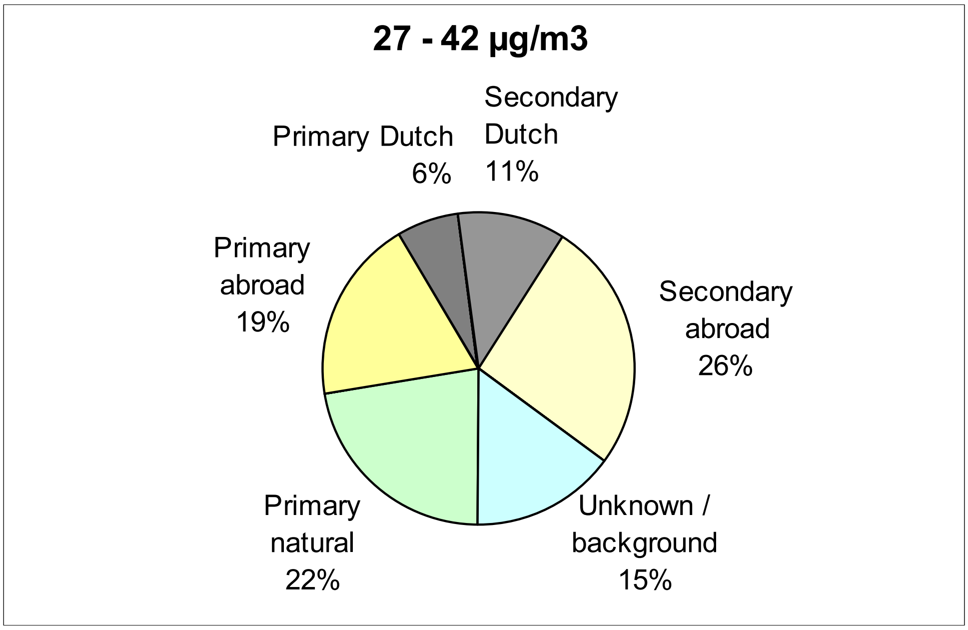

Figure 1.1 *Estimate of the annual average PM_{10} contributions of various sources to aerosol levels in the Netherlands [NAP].*

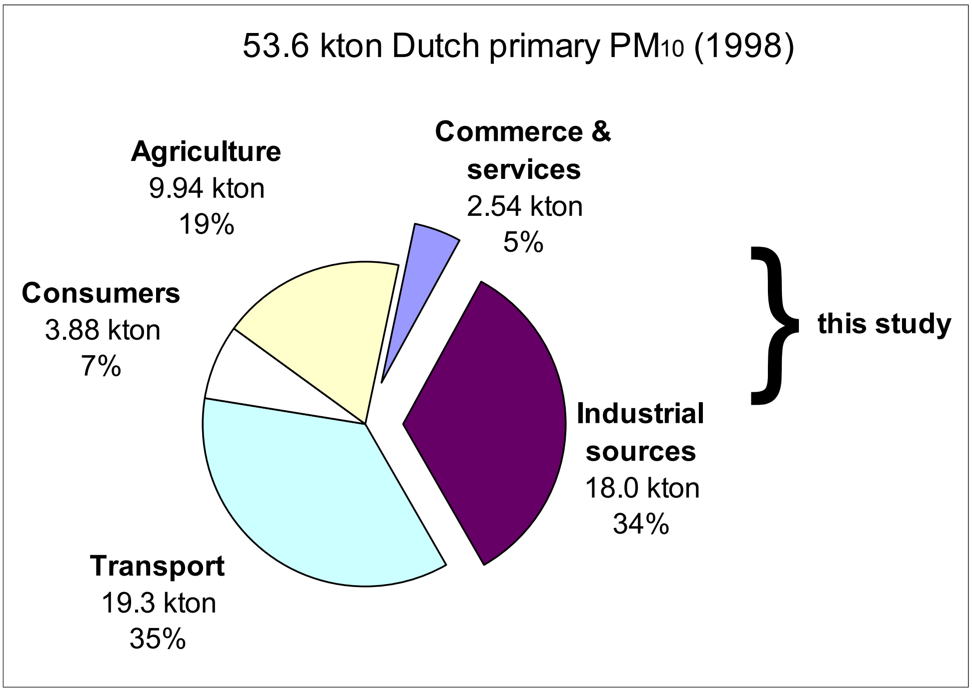

Figure 1.2. *Dutch primary PM_{10} emissions in 1998 presented by sector, illustrating the importance of the selected sectors for the present study, industrial sources and commerce & services.*

At this moment there is no national legislation that sets limit values to the emission of PM_{10}. In most cases there are legal restrictions only to the allowable concentration of total particulate in main process waste gases, e.g. the Dutch National emission Directive NeR. Furthermore, on a European scale Reference Documents on Best Available Techniques (BREF's) are under development by the European Integrated Pollution Prevention and Control (IPPC) Bureau. The Best Available Technologies described for sectors become probably required state of the art technology in 2010.

Summarising, there is a need for answering the following policy related questions:
- Is reduction of PM_{10} and $PM_{2.5}$ emissions from industrial sources in the Netherlands an effective and cost-effective option?
- What are cost-effective reduction strategies for mitigation of PM_{10} and $PM_{2.5}$ from industrial sources in the Netherlands?
- What are the consequences for the Dutch industry in terms of annual costs and the split-up of costs between industrial sectors?
- What are the main characteristics of different categories of policy instruments to implement such a reduction strategy?

1.2 Aim

In order to address the previous policy questions, the aim of the project is:
- to estimate the reduction potential, emission impacts and costs of measures to reduce primary PM_{10} and $PM_{2.5}$ emissions from industrial sources in 2010 in the Netherlands in various variants and discuss the implications for several policy measures.

This study will focus on industrial sources as defined by the Dutch target groups Industry, Refineries, Energy sector and also address separately the storage and handling activities in the Commerce and Public services (HDO). Both combustion and process (diffuse and non-diffuse) emissions will be treated.

2. Approach

2.1 Methodology

The calculation of emission reduction costs of policy measures in the future requires a quite elaborate procedure that is followed consistently. An overview of the main elements of this procedure is depicted in figure 2.1. It consists of an upper and a lower part, the upper part on the assessment of the present situation in the base year being a starting point for the lower part on the assessment of possibilities for emission reduction in the future.

For the base year, data are needed on emissions (inventory) and processes and technologies presently in place. Together with general techno-economic data on reduction technologies, reduction costs curves can be calculated that indicate at what costs which reduction potential is available at specific sources and processes.

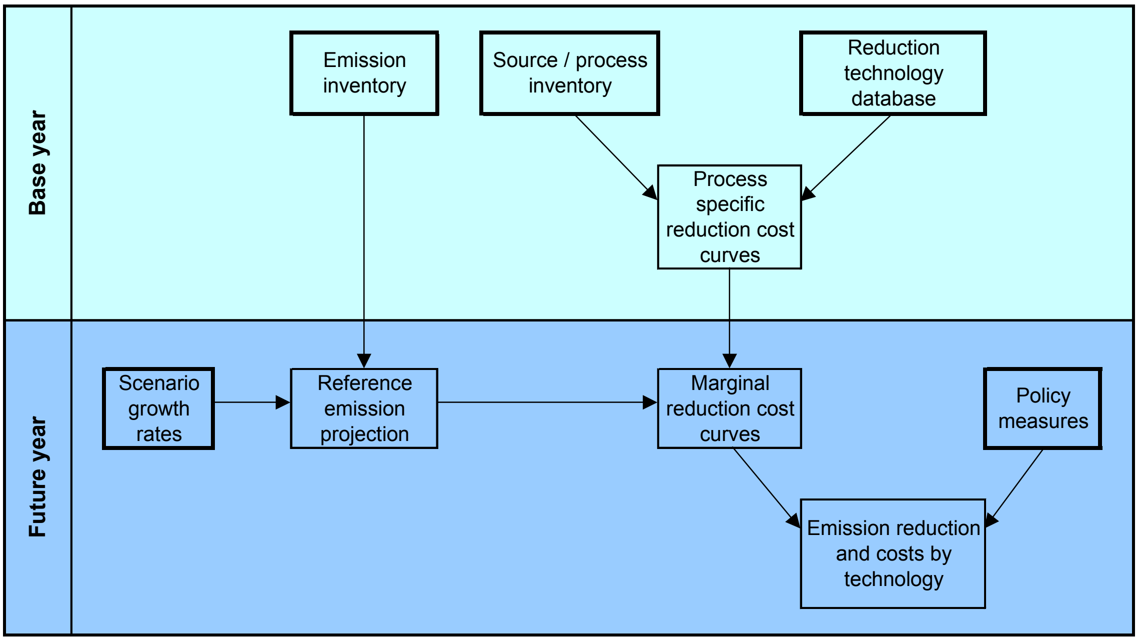

Figure 2.1 Schematic overview of the methodology applied to calculate the emission reduction costs of policy measures for industrial sources of PM in the year 2010.

For a future year, emission projections are made using scenario growth factors. These emission projections form the starting situation for the application of the reduction cost curves. These are being used to calculate the effect of policy measures such as emission objectives, regulation or taxes expressed in terms of emission reduction and costs for each technology, source and sector.
This methodology will be described for each element in more detail in the next paragraphs.

2.1.1 Emission inventory

Emissions of particulate matter (PM) are annually registered in the Dutch Emission Registration (ER). Both PM with a diameter of 10 µm or smaller, as well as with a diameter larger than 10 µm are being recorded. This database, which is centrally managed by TNO consists of two parts: The Individual (ERI) and the Collective Emission Registration (ERC). These systems are complementary, together they account for the total emission.

The ERI is based on a self-reporting mechanism by large industries, whereas the emissions from ERC are estimated as an addition to ERI using generalized methodologies. In order to be included in ERI the plant/site's emission has to be above a certain threshold value or the plant/site has to be selected by the province authorities for other reasons.

In recent years a change in registration methodology has resulted in a larger collective part at the expense of the ERI. The most recent year for which PM emission data is available in the ER is 1998. This will be the base year in the study.

In this study the emission data used have basically been taken from the ER. However, there have been a few additions to the ER data. Due to concern caused by the relatively high ambient levels of PM_{10} in the Netherlands several additional studies to missing PM sources have recently been performed. For the larger part the results of these studies have not yet been incorporated into the ER since they are not fully validated yet. In this study however a large part of the additional material has been used. The main addition consists of an estimate for fugitive emissions from small industries. These diffuse factory building emissions are used as reported by Haskoning [2000]. These are calculated from measurements of exposure concentrations for Arbo (Working place safety) and the total ventilation flow. The idea behind this estimate was a potentially considerable collective contribution from these sources although emission from individual companies might appear small and are hence neglected otherwise.

Since the ER system does not contain any data related to $PM_{2.5}$, the study team has prepared an own estimate for the $PM_{2.5}$ emission. Basically all sources have been regarded in order to estimate the fraction < 2.5 µm of the PM_{10} emissions in a source by source manner. Several projects have already been performed to this subject at TNO-MEP in which particle size distributions have been prepared for nearly all relevant sources of PM. Naturally, this study builds on this material. The main improvement lies in the fact that $PM_{2.5}$ fractions are estimated at a more detailed level, so on source or process specific level instead of general process (combustion) or sector level.

2.1.2 Emission projections

Besides for the current situation (approximated by the 1998 data) this study also regards the years 2005 and 2010. Therefore an emission projection is needed. For this, the physical development of production output as projected by the Dutch Central Planning Bureau (CPB) has been used as in indicator of the emissions. This is a commonly used approach. The physical developments are expressed in growth factors for the future years as an index of the year 1998 (1998=100%). These growth factors are available on a fairly high aggregation level of sectors. The actual emission calculation takes place at a more detailed level of emission sources.

The growth factors have been multiplied with the 1998 values of PM_{10} emissions to calculate the PM_{10} emissions for the years 2005 and 2010. By doing this, it is assumed that the concentration of particulates in the airflows from processes remains constant over time. This means that the present level of installed abatement technologies is fixed, also called ‘frozen technology’. Therefore, it is the Reference case which is the starting point of the calculation of emission reduction by additional abatement technologies and reduction costs.

Multiplying the PM_{10} emissions with $PM_{2.5}$ fractions results in the $PM_{2.5}$ emissions, herewith assuming that this fraction is constant over time at the level of emission sources and processes when the abatement technologies applied are also unchanged.

In the present report, scenario data have been used for two different CPB scenarios, viz. the Global Competition (GC) scenario and the European Coordination (EC) scenario, both representing different developments at national and global scale. In the Global Competition scenario market forces and economic development are the main issues in this scenario world. The European Coordination scenario represents a more coordinated world at least at the European level. The Global Competition scenario is used in most environmental studies as a starting point since it has the highest production growth and a slightly less emphasis on the growth of heavy industry such as non-ferrous industry and refineries and more on food industry. This leads without additional measures to the highest emission growth, herewith presenting the largest challenge to environmental researchers and policymakers.

Both the EC and GC emission projections for PM_{10} have been calculated. It appeared that the PM_{10} emission growth factor for 2010 is 117% in the GC scenario and 111% in the EC scenario. Since sector differences are also small, it was decided to use only the GC scenario as a reference scenario in the study.

These emission growths refer to the Reference case which is the starting point of the calculation of emission reduction by additional abatement technologies and reduction costs. It is assumed that the concentration of particulates in the air flows from processes remains constant over time. This means that the present level of installed abatement technologies is fixed. $PM_{2.5}$ fractions are also assumed to be constant over time at the level of emission sources and processes when the abatement technologies applied are also unchanged. However, reference $PM_{2.5}$ emissions could have a different growth pattern than PM_{10} emissions due to differences in sector distributions.

2.1.3 Technology database

This study focuses on end-of-pipe options to reduce the industrial emission of PM_{10} and $PM_{2.5}$. The techno-economic data on abatement technologies are therefore the core of the analysis. That is why the detailed description of the technologies and the data applied are being described separately in chapter 3. Here, another important, more general point will be made regarding the present state of the processes and technologies and the level of abatement technologies presently in place. Together with the operation conditions, these are very important to select the right control option for a specific source and to estimate the costs of emission reduction.

The most important variable is the gas flow rate of the waste gas stream and the number of individual emission points. Further relevant information concerns the already installed control equipment, waste gas temperature, the PM concentrations in the off-gasses, possible space limitations and specific particle characteristics in reference to dust stickiness and electrical resistance.

The larger part of these data is recorded in ERI (the number of emission points, abatement techniques, waste gas streams and PM concentrations) although the reference year of this information is 1995, not 1998. The year 1995 was the last year this type of ‘background information’ to emission monitoring was collected consistently. After 1995, large companies report their emissions in Environmental reports in which is it is not obligatory anymore to provide this type of technical information. For this reason, about 20 companies, more or less representative for their sector, have been approached in order to receive their opinion and comments on the used data. Their feedback is presented in paragraph 4.3.

The data that became available through ERI or other sources is in all cases used as the technological state of the art of the whole sector. In other words, the ‘technological fingerprint’ of the ERI has been superimposed on al companies in a sector.

Other information sources used are own information available at TNO and handbooks like the Dutch SPIN documents. All the parameters mentioned have been collected by relevant source category in this study.

2.1.4 Total Annual Cost of reduction technologies

The reported emission data are sorted to branch, process and PM_{10} concentration. Similar process flows are combined, resulting in a mean cost effectiveness on branch level for different processes. The costs are calculated as follows.

Total Annual Cost (TAC) of a reduction technique for a specific waste gas flow is calculated according to the quidelines in document “Kosten en baten in het milieubeleid [Publicatiereeks Milieustrategie nr. 1998/6]” and in the Dutch national emission Directive NeR.

Investment
Investments for emission techniques are calculated, based on the waste gas flow, using specific formulas for each technique that accounts for the size effect on investment. The used formulas are for new installations and originate from literature [Rentz, EPA fact sheets, Infomil and Monografieën RIVM] A waste gas stream of 20,000 m^3/h is used as standard to calculate the costs for flows ranging from 5,000 to 100,000 m^3/h. All investments are calculated for installed reduction techniques, accounting for necessary facilities and pre-treating gas streams. For a specific waste gas stream, total investment costs can differ a factor 2 from the calculated value. In some cases the existing reduction technique can be improved to meet lower emission levels. The costs for this improvement are expected to be 30-50% of the costs for a newly installed technique.

Annual capital costs and fixed operational costs
For this study the annual capital and fixed operational costs are taken together in an annual indirect cost factor (capital interest/depreciation, labour and overhead / insurance). Annual capital costs are calculated from the total investment with an annuity of 0.163 based on a depreciation of 10 years and interest rate of 10%. The fixed operational costs are estimated at 4% of the total investment. Total annual indirect costs are thus estimated at 20% of the total investment costs (annuity of 0.2)

Variable operational costs
Annual variable operational costs comprise of costs for utilities (e.g. fuel, electricity, water, steam, compressed air), waste treatment/disposal. For the different reduction techniques a variable operational cost factor has been calculated per 1000 m^3 of cleaned waste gases on the bases of typical equipment information and cost of utilities based on “DACE-prijzenboekje”. The factors used in this study for the different reduction techniques are bases on average situations in practice (see chapter ‘Emission reduction techniques’ and are as follows:

– Low energy scrubber:	€ 0.5 per 1000 m^3
– High energy scrubber:	€ 2.0 per 1000 m^3
– Electrostatic precipitator (dry):	€ 0.2 per 1000 m^3
– Electrostatic precipitator (wet):	€ 0.5 per 1000 m^3
– Fabric filter (baghouse):	€ 0.4 per 1000 m^3

Selection of relevant sources

There are a number of PM emission sources that are excluded from the cost calculations because the process is more or less unique and the individual contribution is too small to justify a complete evaluation of the control options. Selection of relevant sources has been performed by eliminating sectors/companies that contribute less than 10 tonnes PM_{10} annually, and of which the number of plants operated in the Netherlands is limited to one or two. All sources not complying with this criterion (which includes the vast majority) have been taken into account. In fact, over 95% of PM emissions of the known sources have been considered for the application of reduction options.

In a next selection step, processes with substantial emissions in a branch of industry (> 5 ton/year) and relative high PM_{10} concentrations (> 10 mg/m^3 for process emissions and > 0.5 till 5 mg/m^3 for diffuse emissions from factory building) are selected for the calculation of reduction technologies and costs. Reported emission sources with smaller emissions or lower concentrations are not used for the reduction calculations due to the expected high costs in relation to the particle reduction (bad cost effectiveness) for cleaning these waste gas streams. Besides the small emission sources, emission sources with too little information on waste gas parameters (e.g. concentration, waste gas amount) are also not used. No calculations on reduction techniques are possible without detailed information of the source.

Finally, the reduction potential available in the database appeared to be almost 80% of the total PM_{10} and $PM_{2.5}$ emissions.

2.1.5 Reduction cost-curves and policies measures

The annual costs as described in the previous paragraph can be expressed in unit costs in terms of €/ton reduction by dividing the annual costs by the annual emission reduction. These specific costs can be recalculated into marginal costs, when the costs become dependent from previously implemented options. The marginal costs are the annual costs **additional** to previously implemented options, divided by the emission reduction **additional** to previously implemented options.

The marginal costs curve that is calculated for each emission source or process, consists of emission reduction potentials at a certain marginal costs, presented as rectangles in figure 2.2. These potentials can be aggregated for several sources and sectors at national scale. By ordering by costs, a national marginal cost curve can be produced. This national marginal cost curve can be used to find the cost-effective strategy for a country, starting to implement the reduction potentials up to the desired level of emissions. The choice for options is purely based upon cost-effectiveness, regardless of the source or sector.

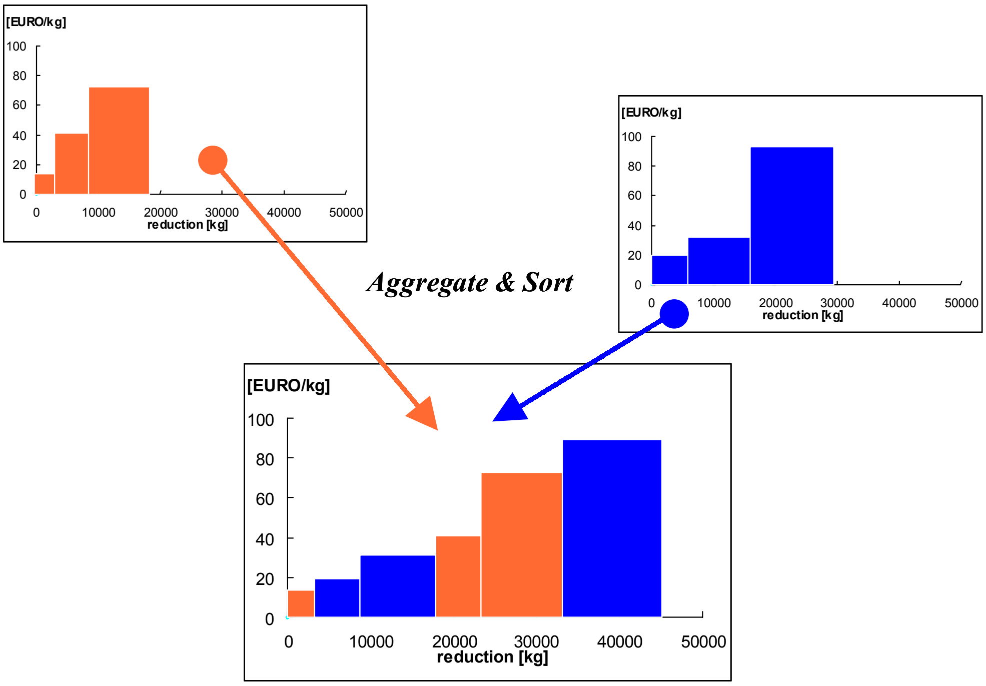

Figure 2.2 Schematic representation of the cost optimisation over two sectors, involving the successive aggregation of two marginal costs curves and sorting of the total of reduction potentials according marginal costs.

It is also possible to calculate the effects of market based instruments such as emission taxes (or tradable emission permits). All options that are cheaper than the tax will be implemented by investors, since it is cheaper to invest than to pay the tax. Vice versa, all options that are more expensive than the tax will not be realised since it is preferable to pay the tax.

2.1.6 Regulatory policies: NeR and BEES

Besides market based policy measures, regulation in the form of air quality standards for flue gases or technology requirements, e.g. such as in the NeR, are important and frequently used policies. These will be addressed by using the type of technology and flue gas concentration levels for each option as a decision criterion for investment. This is explained in the following paragraphs.

For each source, the present concentrations are compared with the concentration limits in the Dutch Emission Regulations (NeR) and the 'Besluit emissie eisen stookinstallaties' (BEES) as they have to be met by new installations. In the NeR / BEES maximum concentration levels are described as total particulate matter (TPM), instead of PM_{10}. Actually the levels should be adjusted for PM_{10}. However, in most cases a reduction technique has to be used to meet the requirements of the NeR. After such a reduction technique, the remaining emission consists for 80-99% of PM_{10}. This makes the error in not accounting for the PM_{10} fraction small compared to the uncertainty ranges of other data and formulas. For cyclones the PM_{10} fraction of the remaining emission is much lower, but cyclones are rarely used as additional techniques in any process to reach the NeR / BEES concentration limits.

According to general NeR regulations, all process emissions with an unabated mass flow larger than 0.5 kg/h, have to be equipped with filtrating separators, if possible (e.g. temperature < 250°C and relative humidity < 90%). In that case the remaining emission concentration has to be below 10 mg/m^3. These regulations apply on normal dust, without carcinogenic properties. For processes with hygroscopic or sticky dust, waste gases can be heated or the filtration material can be pre-coated. For all other process emission where filtrating separators cannot be applied, emission concentrations of 25 mg/m^3 are permitted. For specific processes, separate emission guidelines from 'Bijzondere regelingen voor specifieke processen' in the NeR, or from BEES for new large scale combustion plants are applied. In BEES regulations on large burners, dust concentrations are dependant of the used fuel. See table 2.1.

Table 2.1 Strictest regulation in BEES for emission levels of new large-scale combustion plants [1].

Fuel	Emission level [mg/m^3]
Coal	20
Oil	50
Refinery gas	5
Cokes oven gas	20
Blast furnace gas	10
Oxy-gas	20
LPG	5
Other	5

In the ER data, fuel types are not always reported, making decisions on emission levels from BEES regulations difficult.

2.2 Cases and policy aspects

Besides the macro-economic developments according to the Global Competition scenario, several emission reduction objectives have been expressed in separate cases. These cases also consider to some extent different reduction strategies or policy measures. The cases will be presented in two sections. The first section presents cases with agreed measures and policies in pipeline and the second section explores possibilities for additional emission reduction.

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[1] Burner replacement leads for gas fired plants with a capacity smaller than 10 MW to a more strict required NO_x emission level of 70 instead of 150 mg / m^3. However, there is no additional requirement for dust emission levels.

For all cases, the results in terms of PM_{10} emissions, reductions and costs will be presented per industrial sector for the year 2010 according to the Global Competition scenario. All cases refer to emissions and reductions of PM_{10}. The correspondence, difference and interaction of PM_{10} and $PM_{2.5}$ emissions and reductions, as well as the use of general emission concentration limits are being explored in a separate section 'Some policy aspects'.

The following cases will be presented:
- Agreed measures: Implementation of presently **Agreed measures** only;
- NeR+: stringent implementation (regardless of costs) of the present Dutch national emission directives **NeR+**BEES;
- 50% reduction or 60% reduction: cost-effective implementation schemes to reach **50% reduction** and **60% reduction** targets with respect to the reference development (frozen technology);
- Technical feasible: implementation of the total reduction potential that is **technical feasible**, regardless of costs.

These cases will be explained in more detail in the following paragraphs.

Agreed measures
A number of measures are not implemented yet but are already agreed upon and scheduled to be implemented before 2010 regardless of future (inter)national policy. These measures are agreed upon and reported in Environmental reports of large companies.

NeR+
At present, the Dutch directives NeR and BEES are almost completely implemented. Only some effects could still be in the pipeline up to the year 2010, for instance due to the replacement of an old technology by a new one, that has to fulfil more strict specifications under BEES. One major limitation of the present NeR is that measures more expensive than Dfl 5 or 2.3 € per kg TSP are not obligatory. In the presented case on NeR and BEES, this restriction is abandoned. Therefore, more expensive reduction measures have to be taken as well. In fact, each NeR measure has to be implemented, regardless of the costs. It is therefore referred to as 'NeR+'. This way, the technological potential of the NeR is being investigated. For a more detailed description of the Dutch NeR and BEES directives, see the previous section 2.1.6 Regulatory policies: NeR and BEES.

Other regulation that is being under development at European level is currently publicly available in the form of European Reference Documents on Best Available Techniques (BREF's). It is important to compare these future international requirements with the Dutch NeR and BEES directive, in order to assess what additional effort could be expected to become necessary to meet European standards. This can only be a partial analysis since these documents are not yet available for all sectors. Therefore, it is presented separately in section 5.1.2 EU policies.

50% reduction and 60% reduction

In order to explore further reduction, two cases are being reported following cost-effective ways to reach emission reduction objectives of 50% and 60% with respect to the reference emission development (based upon ‘frozen technology’). These reduction objectives are chosen arbitrary, and are meant to illustrate the possibilities and consequences of more severe emission reduction policies and strategies. Since it concerns cost-effective emission reduction, the cases reflect the most optimistic financial impact to meet the given reduction objectives.

Technical feasible

As a marking point, also the technically feasible reduction potential is presented, regardless of costs, illustrating the total reduction potential available in the database. This indicates whether technology availability is a constraint for reaching reduction objectives.

3. Emission reduction technologies

In this study a variety of emission reduction techniques are used. This chapter gives short descriptions of the end of pipe techniques, and some characteristics, e.g. costs, efficiency and applicability. The actual or future application of technologies in sectors is not presented here but in Appendix D.

The most common techniques that can be considered as Best Available Technologies (BAT) for reduction of dust emissions from industrial waste gases are:

- Mechanical collectors (Cyclones);
- Wet scrubbers (High and Low Energy Scrubbers);
- Electrostatic precipitators (Dry and Wet);
- Fabric filters (Baghouses).

Some other techniques that have the potential to become BAT in the near future are:

- Absolute filters (HEPA, ULPA);
- Ceramic filters.

Table 3.1, 3.2 and 3.3 summarize the characteristics of the applied reduction techniques. Further information on the techniques is given in the separate paragraphs below.

Table 3.1 Application characteristics for emission reduction techniques.

Technique	Particle		Waste gas stream	
	Size (μm)	Characteristic	Temperature (°C)	Moisture content (%)
Cyclone	10-100	Dry/sticky	< 1000	< 100
Multiple cyclones	3-100	Dry/sticky	< 400	< 100
Low Energy Scrubber	2-100	Dry/sticky	< 500	< 100
High Energy Scrubber	0.1-100	Dry/sticky	< 200	< 100
Electrostatic Precipitator	0.01-100	Dry/sticky	< 400	< 100
Fabric Filter (Baghouse)	0.01-100	Dry	< 300	< 90
Ceramic Filter	0.1-100	Dry	< 800	< 90
Absolute Filter	0.01-100	Dry	< 400	< 90

Table 3.2 Efficiency of reduction techniques.

Technique	**Efficiency (%) for particles size fraction**			**[PM][a]**	**Pressure drop**
	PM $_{0.1}$	**PM $_{2.5}$**	**PM $_{10}$**	**(mg/m^3)**	**(kPa)**
Cyclone	-	-	< 50	75-200	0.2-1
Multiple cyclones	-	< 50	50-90	25-100	1-2
Low Energy Scrubber	-	< 50	50-95	10-100	0.5-3
High Energy Scrubber	50-90	90-95	95-99	5-50	4-20
Electrostatic Precipitator	90-98	95-99	95-99	5-50	0.3-1
Fabric Filter	90-99	95-98	98-99.5	1-10	1-3
Ceramic Filter	90-99	95-98	98-99.5	< 10	2-6
Absolute Filter	> 99.9	> 99.9	> 99.9	< 0.1	3-6

a = PM concentration after reduction technique; lower end of the range is for relatively coarse dust and low loading of the incoming gases; upper side of the range is for relatively fine dust and high loading.

From table 3.2 it can be concluded that (multi)cyclones and low energy scrubbers are not suitable to give a substantial reduction of PM$_{2.5}$ and that the efficiency for PM$_{10}$ depends on the particle size distribution of the dust. For multiple cyclones and low energy scrubbers efficiency can only be high when almost all of the PM$_{10}$ is in the range 2.5 till 10 μm. When this is the case for waste gases normally there is also a lot of dust with diameters > 10 μm. For these cases it is probable, that in the present situation there has already been installed a reduction technique to prevent emission of high amounts of total particulate matter (TPM). So in the present situation two cases concerning the particle size distribution of PM$_{10}$ for the emitted waste gases will be encountered.

For processes with mechanical and/or mild heat treatment (e.g. drying, grinding, crushing, transfer etc.) emitted dust will have particles in the range 2.5 till 10 μm. as well as < 2.5 μm. For high temperature processes (e.g. furnaces, incineration etc.) most of the particulates are < 2.5 μm,

To further reduce the emissions of both categories with more than 80% basically only high energy scrubbers, electrostatic precipitators and fabric filters are applicable. For application of these reduction techniques for both categories there isn't a big difference between reduction efficiency for particles in the range 2.5 till 10 μm as opposed to particles < 2.5 μm. So in a first order estimation the application of a reduction technique in situations where at this moment no techniques are used and in cases of an extra reduction technique a reduction of more than 90 % will be the result for PM$_{10}$ as well as PM$_{2.5}$.

For already used reduction techniques that can be optimised (e.g. additional stage, higher pressure, better filter material etc.) it is expected that this optimisation has an efficiency of about 75% in relation to the present emission concentration for PM$_{10}$ as well as PM$_{2.5}$.

Table 3.3 Total capital investment and running costs for emission reduction techniques.

Technique	**Investment**[a] **(€ per m³/h)**	**Running costs**[b] **(€ per 1000 m³)**
Cyclone	1-2	0.05-0.15
Multicyclone	2-5	0.2-0.5
Low Energy Scrubber	1-5	0.2-1
High Energy Scrubber	5-20	1- 4
Electrostatic Precipitator (Dry)	10-30	0.1-0.3
Electrostatic Precipitator (Wet)	20-80	0.1-0.3
Fabric Filter (Baghouse)	10-25	0.2-1

a = Total capital investment (equipment, installation and indirect) is based on flow rates between 5,000 and 100,000 m^3/h.

b = Running costs (operation, maintenance, utilities, overhead, insurance) are based on flow rates between 5,000 and 100,000 m^3/h and are expressed in € per 1000 m^3 cleaned gases on a yearly base for almost continuous running of the installation.

3.1 Mechanical collectors

Working principle

Most important versions of mechanical collectors are cyclones and multicyclones. In cyclones, the waste gas stream is tangentially introduced in a cylindrical chamber. The centrifugal forces drive dust particles to the wall of the cyclone. The particles at the side fall down and are removed from the bottom of the cyclone, the cleaned air is removed form the top. To improve efficiency, water can be sprayed at the dust particles to increase agglomeration, this is called a wet cyclone.

Application for removing fine particles (PM_{10})

Mechanical collectors are only efficient for removing particles > 10µm. The remaining emissions are relative high, and these techniques are generally used in combination with other techniques (as a prededuster). The mechanical collector removes the larger particles and a second technique, e.g. a fabric filter, removes the particles < 10µm. Particle size, flow size and dust loading determine the efficiency. Mechanical collectors are mainly used in agricultural and metal processing industries.

Latest developments

A relative new development is the rotating disc precipitator. A rotating filter is placed in the outlet stream of a cyclone. The filter consists of small channels, several mm in diameter, which is rotated around its axis at 3000 rpm. The centrifugal forces push the particles to the walls of the channels. The channels have to be cleaned with compressed air in the opposite direction of the waste gas flow. The agglomerated dust is blown back in the cyclone where it can easily be removed.

3.2 Wet scrubbers

Working principle
The waste gas stream is passed through a washer where water spray removes the dust particles from the gas stream. The dust particles are collected in water drops, and removed from the bottom of the washer. The clean air is removed from the top. To create more surface area for contact between droplets and particles a packed bed scrubber can be used.

Application for removing fine particles (PM_{10})
Wet scrubbers use several methods of gas-liquid mixing in washing sections and/or are based on pressure drop. These scrubbers are better suited for moist gas-streams and sticky dust then dry dust collectors. Coarse dust collection (> 10 µm) is performed with low energy scrubbers (spray-tower, packed tower and dust scrubber), with pressure drops ranging from 0.2 –3 kPa. For collecting fine dust, high-energy scrubbers (e.g. venturi and rotation scrubbers) are used, with pressure drops ranging from 3 to 30 kPa. Some disadvantages of wet scrubbers for removal of fine dust are high energy consumption and water pollution.

Latest developments
The latest techniques for wet scrubbing are focussed on higher efficiencies with lower pressure drops and lower energy use. These techniques use the same principle as for the mechanical separators, namely agglomeration of fine dust to larger particles. For scrubbers, the most promising techniques are force flux condensation (FF/C) and electrostatic scrubbers. In force flux condensation agglomeration is enhanced by condensing steam on the particles. The dust particles are then removed in a wet cyclone or low-pressure venturi scrubber. For high temperature (>300°C) waste gas flows, this technique is very useful. The hot gas flow is used to evaporate water that is used to agglomerate the particles. Colder waste flows contain not enough energy to evaporate the water, and steam has to be used to condensate on the particles but this is very expensive when unused steam is not available from another process in the plant.

3.3 Electrostatic precipitators

Working principle
In electrostatic precipitators, dust particles are electrically charged by a positive electrode, and then collected at a negative electrode. The collecting electrode is cleaned by shaking (dry) or rinsing with a liquid (wet). Electrostatic precipitators are mainly used for small dust fractions.

Application for removing fine particles (PM_{10})
Electrostatic precipitators can be divided in two classes. Dry electrostatic precipitators (ESP) can be used for removing very fine particles (<0.3µm) at high tempera-

tures (up to 400°C). For sticky dust particles the electrodes are cleaned continuously with a liquid (wet ESP or WESP). Most important characteristics for emission reduction efficiency are particle size, dust loading, electric conductivity, specific precipitation surface and power supply. Conductivity of the particles can be influenced by addition of SO_3. A disadvantage of electrostatic precipitators compared to fabric filters is that the efficiency depends on the physical end electrical properties of the dust particles. Electro filters are mainly used in cement industry, coal fired power stations and waste incinerators.
Typical industrial applications of dry ESP are utility boilers (coal, oil), industrial boilers (coal, oil, wood, liquid waste), chemical industry, Primary and secondary metal industry, Petroleum refineries, Mineral product, Wood, Pulp and Paper industry, Municipal waste incineration. Wet ESPs are commonly used by textile industry, Pulp and Paper industry, Metallurgical industry, Coke ovens, Hazardous waste incineration and Sulphuric acid manufacturing plants.

Latest developments
New developments focus on higher voltages, with suppressing electric sparks (Electrostatic Space Cleaner Super or ESCS). By applying pulsating power supply, a more constant power distribution at the collecting electrode is established. The shorter pulsing times also reduce the voltage on the filter, before the ion cloud reaches it, thereby preventing electric sparking. A second advantage of pulsating power supply is energy savings of up to 50%.
The efficiency can be further increased by continuous cleaning of the electrodes by rotating brushes (Moving Electrode Electrostatic Precipitator or MEEP) or by two additional electrodes. A positive electrode in the input and a negative electrode in the output flow. The space between the electrode can be filled with electrically charged granulates, usually aluminium oxide, which collect the dust particles. This enhances the efficiency of the electrofilter.

3.4 Fabric filters

Working principle
The gas stream is passed through a woven or non-woven fabric filter, and dust particles “adhere” to the fabric or to already collected dust particles. The collected dust is removed from the filter by compressed air or shaking of the filter. The filtered dust is collected at the bottom and removed from the chamber (baghouse). Cleaned type fabric filters have nearly constant effluent particle concentration independent of particle loading.

Application for removing fine particles (PM_{10})
When cleaning moist waste gas streams, dust can stick to the filter, thereby blocking the flow through the filter. To avoid this a combination of condensation by cooling and reheating of the waste gases can be used, but usually fabric filters are only used for relatively dry waste gases. For waste gases with sticky the fabric can

be pre-coated with dry dust (e.g. lime) after each cleaning cycle of the fabric by dispersion of particles in the waste gases to be cleaned. For hot gases this can be done by injection of a slurry of particles (e.g. lime milk); in this way the temperature of the waste gases can be cooled to the temperature needed for the application of fabric filtration (200 – 250 ºC). Most important characteristics for dust removal efficiency are surface loading, particle size and fabric material. Fabric filters are used in all types of industry.

Latest developments

For fabric filters, new developments focus on predicting and lowering the pressure drop over the filter, the use of high temperature resistant materials and the development of compact filter elements (pleated cloth). The filters can be cleaned with sound waves, to remove dust from inside the filter material. This suppresses the increase in pressure drop over time. Dust particles can be electro statically charged to create a more porous dust layer on the filter. The most cost-effective method to improve efficiency of fabric filters is addition of a suitable aiding substance (e.g. lime) to the waste gas stream. Future developments will probably be focussed on decreasing pressure drop, extension of filter lifetime, increasing surface tension (air/filter rate) and predicting efficiencies based on dust particle characteristics.

3.5 Absolute filters

Working principle

Absolute filters are like conventional fabric filters with small pores at the surface (e.g. a layer of PFTE membrane). Dust particles are collected only by the sieve effect at the outer surface of the filter, due to the very small size of the outer pores, leading to very high efficiencies. They are classified by their minimum collection efficiency. HEPA (High Efficiency Particulate Air) filters have by definition a removal efficiency of more than 99.97% for particles of 0.3µm. ULPA (Ultra Low Penetration Air) filters have by definition a removal efficiency of more than 99.9995% for particles of 0.12µm. Some extended media filters are capable of much higher efficiencies. The collection efficiency increases with increasing filtration velocity and particle size and with dust cake thickness and density. Both types of filters have overall efficiencies that vary with particulate loading.

Application for removing fine particles (PM_{10})

Absolute filters generally contain a paper media and are best applied in situations where high collection efficiency of submicron PM is required, where toxic and/or hazardous PM cannot be cleaned from the filter and are typically used in applications involving chemical, biological and radioactive PM. The filter media is pleated (extended media filters) to provide a large surface area to volume flow rate. Flow rates through these filters are very low, 0.0025 m/s, and therefore only applied in industries with high value or highly toxic dust particles and/or if the air has to be recycled to the room to reduce energy for heating or in dust proof areas. Often they are installed as the final component in a particulate collection system, downstream from devices such as electrostatic precipitators or baghouses to remove large particles and high particulate loadings. Because of the limited possibilities for cleaning these filters frequent filter replacement is needed, which can be very expensive. Filter systems are designed to replace filters outside the collector housing. This makes them ideal for applications involving HAPs or toxic particulate. The collected particulate is tightly adhered to the filter media for subsequent disposal. Besides the use in mixed waste incineration installations the filters are used in clean rooms, laboratories, food processing, pharmaceutics and microelectronics.

Latest developments
The latest filters have a top layer of porous acryl foam or sintered plastic powder. Most common shapes are cartridge filter and candle filters. The filters are cleaned by blowing compressed air through or along the surface of the filter, or by creating a vacuum. The filter surface can be increased with ridged filters, thereby decreasing the pressure drop over the filter. Energy savings of 20-30% can be achieved. Newer filter designs utilizes recently developed fine glass fibre technology.

3.6 Ceramic filters

Working principle
Ceramic filters use the same removing principles as fabric filters, but are applicable for high temperature applications (up to 800°C). The filters made of ceramic material, sintered metal or thin foils and are shaped as cylinders, with one open side. The air can be passed through the filter from the inside or the outside, but because of mechanical and thermal vulnerability of the filters, filtration from the inside is recommended. The filters can clean high volume gas streams in compact installations, up to 300 m^3/h per m^2 of ceramic surface. The filters are cleaned with high-pressure air pulses. Ceramic filters are the best available technology for high temperature applications.

Application for removing fine particles (PM_{10})
For high temperature gas stream, ceramic filters are more efficient than fabric filters, and research will be directed towards these ceramic filters.

Latest developments
To decrease pressure drop over the filters, new materials are applied. A top layer of fine SiC granules and mineral fibres on a porous SiC carrier, results in a lower pressure drop (0.35 kPa at 200 m^3/m^2h). Several techniques to remove dust from the filters are being developed. Cross-flow filters are cleaned by passing the incoming gas stream along the filter. The gas stream is forced to pass along the filter, before and after filtration. The advantage of this technique is a very good surface/volume ratio.

3.7 Materials handling emissions

Important PM emissions are caused by material handling operation in the outside air. It concerns both industrial sources and the sector Commerce & public services (in Dutch Handel, Diensten en Overheid). In the NeR a specific instruction is available to prevent PM-emissions caused by handling and transport of materials that are sensitive to dust rise in the environment. The NeR states that there has to be no visible emission of PM in the direct surroundings of the handling operations. The measurements to be taken to accomplish this depend on the sensitivity to dust rise of the material. Five classes of materials have been defined:

- S1: very dusty, not wettable;
- S2: very dusty, wettable;
- S3: moderate dusty, not wettable;
- S4: moderate dusty, wettable;
- S5: hardly or not dusty.

Almost all materials that are handled in industry are classified in one of these classes. Depending on the class of the material and the specific handling operation different measures have to be taken to prevent diffuse emission. The handling operations that are distinguished are: loading/unloading of trucks, railcars, ships; unloading in hoppers; loading/unloading by grippers; continuous mechanical transport; pneumatic elevators; storage in piles or silos; traffic on the factory site.
For the materials belonging to the classes S2 and S4 emissions have to be minimized by handling and processing under humid or wet conditions. In that case PM emissions can be reduced to about 10 g per ton of processed/handled materials.
For class S1 (not wettable) these operations have to be done (if possible) in closed environments for very dusty material with ventilation and dedusting equipment (e.g. fabric filters).

For operations outside with less dusty material (S3: not wettable) measures to be taken can be technical (special partly-closed constructions, covering, windshields) and/or behaviouristic (no handling with high wind speed; maximum unloading height, unloading underneath windshields; wet or chemical suppression and/or cleaning pavements; driving trucks with low velocity). Many of the mentioned measures are not yet generally used and are placed on the VAMIL-list to promote investment in these measures. To further reduce emissions from handling en transport the above mentioned measures can often be executed more strictly or more intensive.

In TNO-MEP report R 96/252 cost effectiveness of some relatively new techniques for handling operations are given. For this study these techniques are divided in two categories in respect to cost effectiveness. A distinction between cost effectiveness better than and worse than € 5 per kg reduced PM emission is made because of the fact that NeR takes a value of 2.3 €/kg (Dfl 5 per kg) as an indicative reference for costs to be acceptable for reduction of total particulate matter (TPM).

Because of the fact that PM 10 is only a part of TPM a value of € 5 per kg reduced PM_{10} emission is chosen. It is expected that measures with cost effectiveness < € 5 per kg have reduction efficiencies of about 30 % to 90% and more expensive measures about 80 to 99% in respect to uncontrolled operation [EPA, 1992]. In the present situation some cost effective measures according to NeR are already taken; so additional measures will have lower efficiencies in respect to the present situation.

Cost effectiveness and expected efficiencies of additional technical measures to reduce diffuse emissions:

- < € 5 per kg (efficiency about 50%):
  - loading/unloading: vertical screw, horizontal loading mechanism, closed hopper, almost closed grabber, combination of pneumatic/grabber, continuous unloading;
  - internal transport: turning elevator, conveyor belt without rollers, wet/chemical suppression of paved roads;
  - storage piles: additives, windshields.
- € 5 - € 50 per kg (efficiency about 80 %):
  - loading/unloading: air slides, pneumagrap;
  - internal transport: closed belt conveyor;
  - storage piles: walled storage, roofing-in.
- > € 50 per kg (efficiency > 90%):
  - storage piles: self-constructing cover, domes (concrete spherical closed covers).

These reduction potentials and costs have a large uncertainty. The data have been used for material handling emissions in industry to complete the emission reduction options from industrial sources. However, the data have been considered to be too uncertain to estimate the emission reduction potential and costs for the sector Commerce and Public services as a whole. Additional research is needed to make a useful estimation of reduction and costs.

Not generally used and new developments in reduction techniques for storage and transport operations for specific braches of industry and/or materials are:

Grain handling (NeR class S3) :

- Extraction and cleaning of air from hoppers and pneumatic transport;
- Closable land hopper for unloading ships (PM reduction 70%; investment € 200.000);
- Edible oil suppression system (PM reduction > 75%; low costs: € 0.2 per ton grain);
- Aspiration systems on silos with dedusting.

Flour industry S3 [Milieuinformatie Meelfabrieken]:

- Closed hanging belt conveyers;
- Flexible flap system for turnover of bulk materials;
- Two stage filter (Cyclone – fabric filter);
- Special mechanical belts;
- Aspiration systems on silos and hoppers with dedusting.

Compound feed S3 (Cattle feed) [Milieuinformatie Mengvoederindustrie]:

- Closed hanging belt conveyers;
- Flexible flap system for turnover of bulk materials;
- Wind separator
- Water mist / micro foam dedusting;
- Closable land hopper for unloading ships (PM reduction 70%; investment € 200.000);
- Special mechanical belts.

Coal fired power stations (coal (S2/S4), Powdercoal (S1), Fly ash (S2)):

- coal storage: chemical stabilization (latex binder).

3.8 Fugitive emissions from factory buildings

For reduction calculations of factory building emissions a separate technique is used. Building ventilation waste gases are generally very large, with small dust concentrations (0.5-5 mg/m^3). Standard reduction techniques therefore result in very bad cost effectiveness. To get better cost effectiveness a combination of waste gas flow reduction and subsequent cleaning is adopted. Source evacuation on emission sources in the building can lead to 80-90% lower waste gas flows. This increases the concentration of dust with a factor 5 to 10. The concentrated waste gas stream can be usually be cleaned with a regular fabric filter. The remaining concentration after reduction is expected to be less than 2 mg/m^3 for the concentrated waste gas stream. Calculated for the original waste gas stream, this would correspond to about 0.2 mg/m^3.

3.9 Integrated measures

Measures such as refurbishment of the production plant, replacement of obsolete plants or technologies or process innovation, are referred to as integrated measures. Often, these options are implemented for other reasons than reduction of particulate matter. In these cases, there are no costs accounted for PM reduction.

This type of measures is mostly taken at plant or company level. The source of information is the Environmental report, if the company has chosen to report such measures. Therefore, it is difficult to estimate the impact of integrated measures.

In the present study, one large integrated measure has been taken into account: the refineries will reach in their firing natural gas standards. This could be done by a switch to natural gas or by (a combination with) other options. It results in a reduction of 50% (approximately 1700 ton PM_{10}).

4. Reference situation

4.1 Present emissions

As has been pointed out in the introduction of this report, emissions from industrial sources account for one third of Dutch PM_{10} emissions. For $PM_{2.5}$ this is less, approximately a quarter of the total national PM_{10} emissions. This is due to the large share of small particulates in exhaust emissions from transport.

The contributions of the different industrial sectors to the total PM_{10} emissions from industrial sources are presented for the base year 1998 in figure 4.1. The Basic metals is the largest emitter of PM_{10}, followed by Refineries, Chemicals, Food and Building materials. These five sectors are responsible for 80% of the PM_{10} emissions and almost 90% of the $PM_{2.5}$ emissions from industrial sources. In sectors such as power generation, already a major reduction has been achieved in the past.

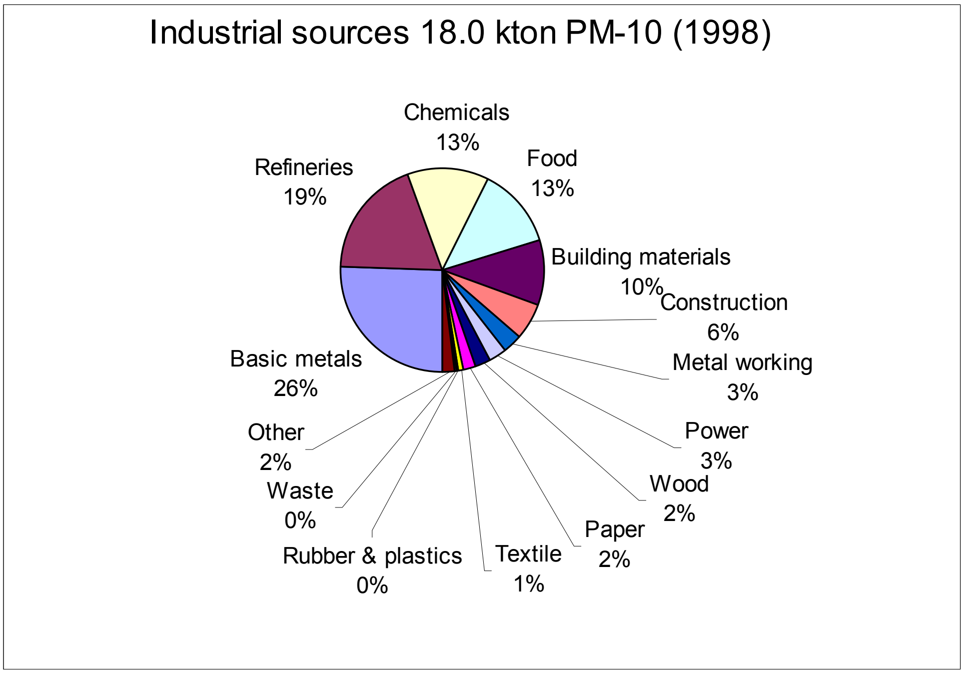

Figure 4.1 PM_{10} emissions of Dutch industrial sources in 1998 presented by sector.

In the basic metal industry various sources are important, ranging from stack emissions from sinter strands to various fugitive sources. In the oil refining industry the combustion of residual fuel oil causes the PM emissions. A well developed industry in the Netherlands is the manufacture food and beverages. In this sector extensive use is made of various types of spray drying towers. Besides fugitive sources the off gasses of the spray dryers are the main contributors. Spray dryers are also employed in the chemical industry, for instance in the manufacture of fertilizer grains and powders. In addition some chemical companies use various chemical wastes as fuel. In some cases this causes relevant PM emissions as well.

In the non-metallic minerals production we distinguish glass, clinker and brick ovens. These are the dominant source types although storage and handling emissions in the cement manufacture are also important. Then there are various types of fugitive emissions in other sectors such as waste treatment, construction and the textile, wood/furniture and paper and pulp industry. In the figure a major contribution is made by "Other sources to be specified". These emissions comprise fugitive dust sources during storage and handling of bulk goods (which will be taken into account in a later stage of this study). Coal-fired electricity generation makes a modest contribution to the total.

All sources but 'other' have been considered for reduction technologies in this study. From the figure it can be concluded that the coverage of this work is quite high: above 95%.

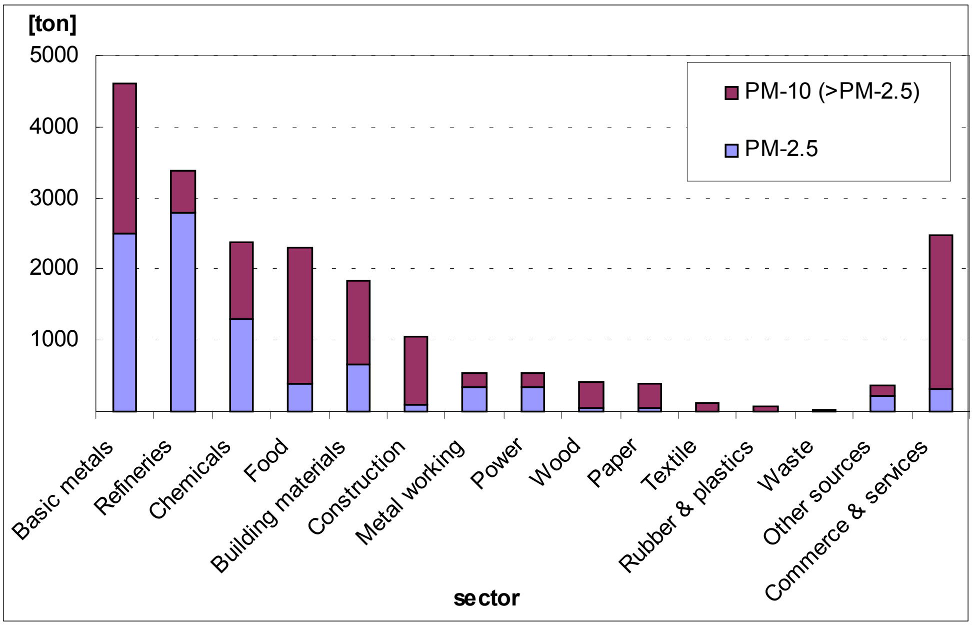

Figure 4.2 PM_{10} and $PM_{2.5}$ emissions by sector in the Netherlands in 1998 in ton.

The emissions by sector are also presented in figure 4.2 in absolute quantities (ton), placed in order from left to right from high emissions to low emissions. This order is used in the presentation of sector results, indicating the importance of the sector in terms of PM_{10} emissions.

In figure 4.2, PM emissions have been split into $PM_{2.5}$ emissions and emissions larger than 2.5 µm and smaller than 10 µm. The sum of these two categories (stacked bars in graph) is the PM_{10} emission. It appears sectors emit PM_{10} in the order of several kton. The PM_{10} emission of Commerce and Public services is comparable with the large industrial sectors.

The figure shows that the share of $PM_{2.5}$ emissions is not the same in each sector. PM emissions from refineries contain a high portion of $PM_{2.5}$, while this share is low in the PM emissions from the sectors Food, Construction, Wood, Paper, Textile and Commerce and Public services. This difference stems from the type of process. Combustion processes lead to a high portion of $PM_{2.5}$ while mechanical process lead to a small share of small particulates. A list of $PM_{2.5}$ fractions by sector in 1998 is presented in the Appendix A. The data of the PM_{10} and $PM_{2.5}$ emissions by sector are presented in a table in Appendix B.

4.2 Emission projection

The emission projection according to the Global Competition scenario for both the PM_{10} (total of stacked bars) and $PM_{2.5}$ are presented for the years 1998, 2005 and 2010 in figure 4.3. Without any measures (frozen technologies) the PM_{10} emissions are projected to grow with 16% from 20.5 kton in 1998 to 23.8 kton in 2010.

Both the EC and GC emission projections for PM_{10} have been calculated. It appeared that the PM_{10} emission in the EC scenario is projected to grow with 10% to 22.6 in 2010. Since sector differences are also small, it was decided to use only the GC scenario as a reference scenario in the study.

Since $PM_{2.5}$ emissions are not equally distributed over sectors and sectors grow with different rates, developments of reference $PM_{2.5}$ emissions could differ from PM_{10} emissions. However, the figure shows that this is not the case. To be precise: $PM_{2.5}$ emissions grow with 18% from 9.1 kton in 1998 to 10.7 kton in 2010. The differentiation in growth by sector is of course rather limited. This can be seen in figure 4.4 that presents the physical production volume growth by sector according to the GC scenario as applied for the calculation of emission developments. The data of the PM_{10} and $PM_{2.5}$ emissions by sector are presented in a table in Appendix B.

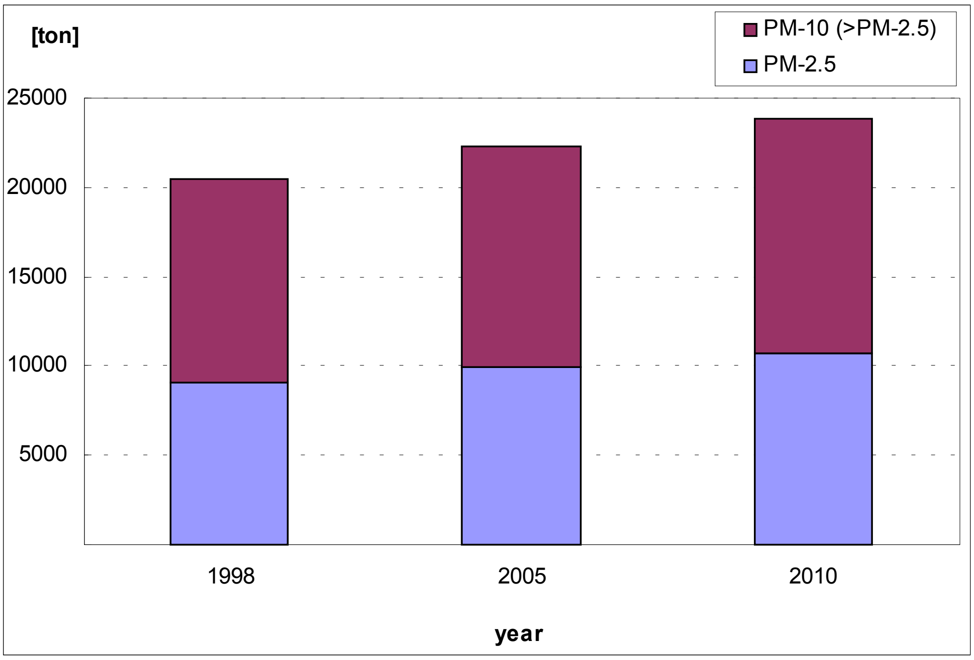

Figure 4.3 *PM_{10} and $PM_{2.5}$ emission projection of industrial sources and Commerce & Public services presented for the years 1998, 2005 and 2010 according to the Global Competition scenario.*

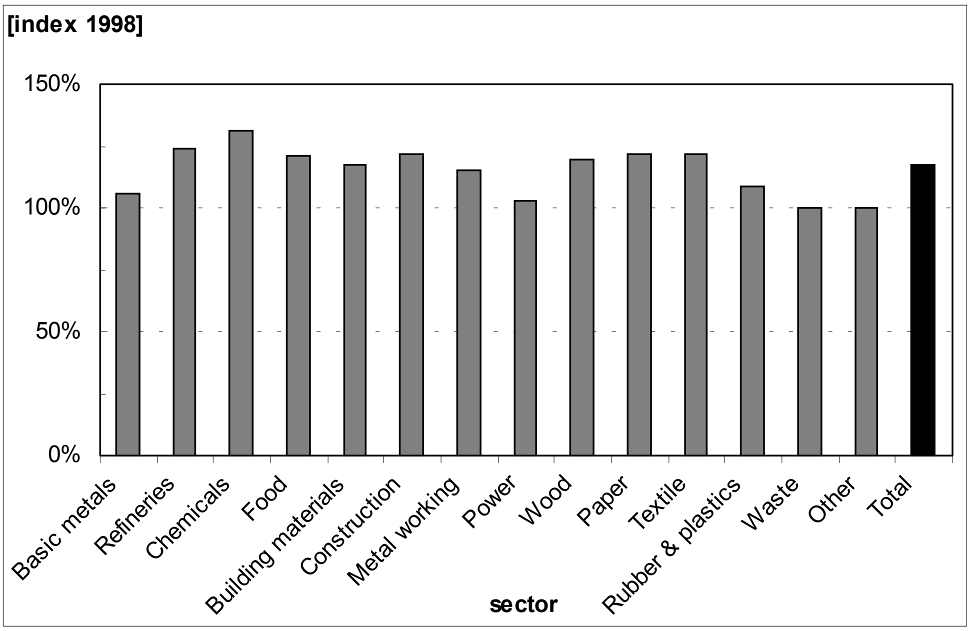

Figure 4.4 *Physical production volume growth by industrial sector according to the GC scenario as applied for the calculation of emission developments.*

4.3 Feedback from companies

The data on technical parameters of the production processes and applied reduction options are reflecting the 1995 situation, the last year that this information has been collected consistently in the Pollutant Emission Register. Developments over the last 5 years have been taken into account for as far as these are known by Environmental reports. These parameters are particularly relevant for estimating the costs of reduction options. In order to get an impression of the present state of developments in the different sectors, a number of (most large) companies have been approached to receive their feedback on the data used for their company (sector). This has been a first step of a dialogue on possible further emission reductions by industrial sources and has revealed some interesting qualitative information.

Some companies indicate to find it difficult to understand the ideas and assessments made on national policy level, e.g. for instance the present study and the data reflecting the situation in the companies. A few reasons are found for this.

The companies report PM in terms of Total Suspended Particulates to the Pollutant Emission Register. The data are processed into PM_{10} and $PM_{2.5}$ values with the use of standard sector and process PM_{10} and $PM_{2.5}$ fractions (of TSP). $PM_{2.5}$ is generally not known in the industry. Even the calculation to PM_{10} gives often difficulties.

Large companies report their emissions to the individual PER in terms of separate emission points (plants, turbine houses, factories etc). The analysis and also policy development takes place at a more abstract level of processes and sectors.

Finally, costs of reduction options can be influenced highly by local circumstances such as existing technologies, building types, space etc. In general, companies point this out but understand that not all details can be reflected in the analysis.

A number of companies stated that PM reduction is indeed a priority for the company, often put on the agenda by municipal authorities for reasons of local hinder. These companies are within or nearby the built environment. In some cases, moving the complete site is perhaps necessary in order to be able to respect the local air quality standards.

The overall impression of the discussions with the companies is that it is generally felt that a more severe policy in the near future would not be realistic in terms of reduction costs. It was expressed that the discussion at policy level is merely effect driven and not in touch with the present economic reality.

5. Emission reduction in 2010

This chapter presents in two parts the results of the analysis on emission reduction options, potentials and costs in the context of the Global Competition scenario in the year 2010. It concerns industrial sources excluding Commerce & Public services since the data on reduction measures in the latter sector are not accurate enough to provide a reliable sector estimation. The first part investigates the present and proposed policies (or even under development), here referred to as agreed measures and policies in pipeline. The section is split up in an analysis on national policies and a discussion of expected EU policies. The second part analyses the possibilities and consequences for further reduction resulting in emissions substantially lower than in 1998.
The material that was the basis for the analysis is presented in more detail at sector level in Appendix D.

5.1 Agreed measures and policies in pipeline

5.1.1 National policies

In figure 5.1 the emission reduction of PM_{10} in 2010 is presented on the horizontal axe that is as long as the projected PM_{10} emission according to the GC scenario in the year 2010. The marginal costs are presented on the vertical axe up to a level of 50 € per kg reduction. The cut off level of reduction costs presently in the Dutch directive NeR is 2.3 € per kg. More expensive options are not obligatory to implement.

Figure 5.1 presents the marginal cost curves for three cases with reference to the reference emission of 21.2 kton in 2010 when no measures are taken (the frozen technology projection presented by the bold vertical line). The steepest line is the marginal cost curve according the NeR+ case. The NeR+ case assumes implementation of the NeR but without a cost cut-off level and also including BEES requirements for new plants. The steepness illustrates that little potential is available at low costs. This means that the low cost measures already have been implemented in the past. The result is that the NeR as it is now, offers not much PM reduction for the future, even if the clause on maximum costs is increased to a higher level of for instance 30 € per kg.

This is illustrated sharply by the case with the lowest curve, the cost-effective reduction. This curve shows a larger reduction potential at relatively low costs. Relatively to the NeR+ case, since the cost-effective case not reaches halved emissions below 50 € per kg.

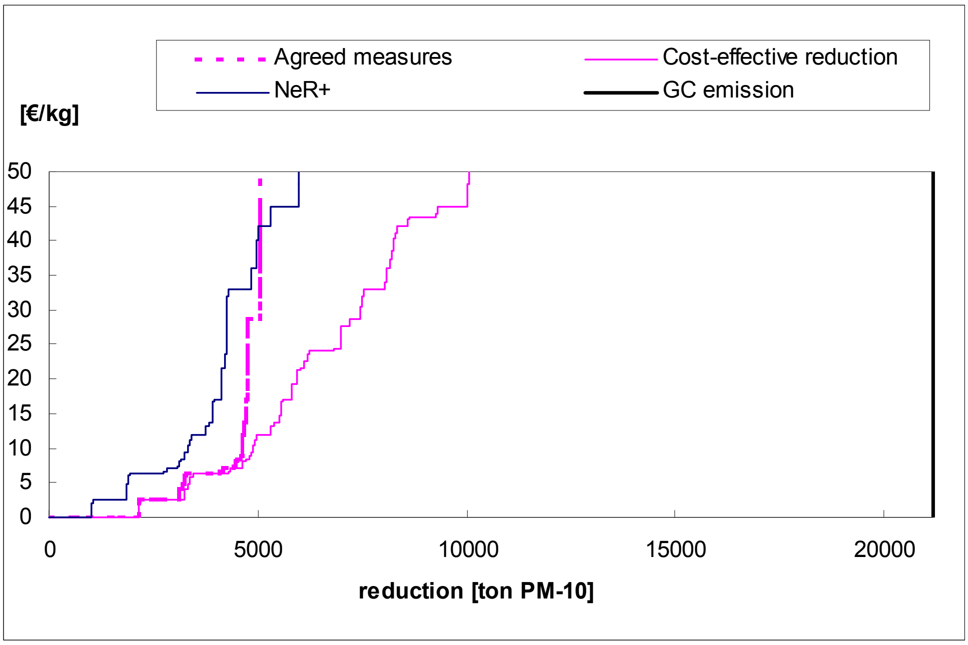

Figure 5.1 *Marginal costs curves for PM_{10} emission reduction by Dutch industrial sources in 2010 in three cases presented with reference to the GC emission without additional measures (frozen technology: solid bold line at 21200 ton).*

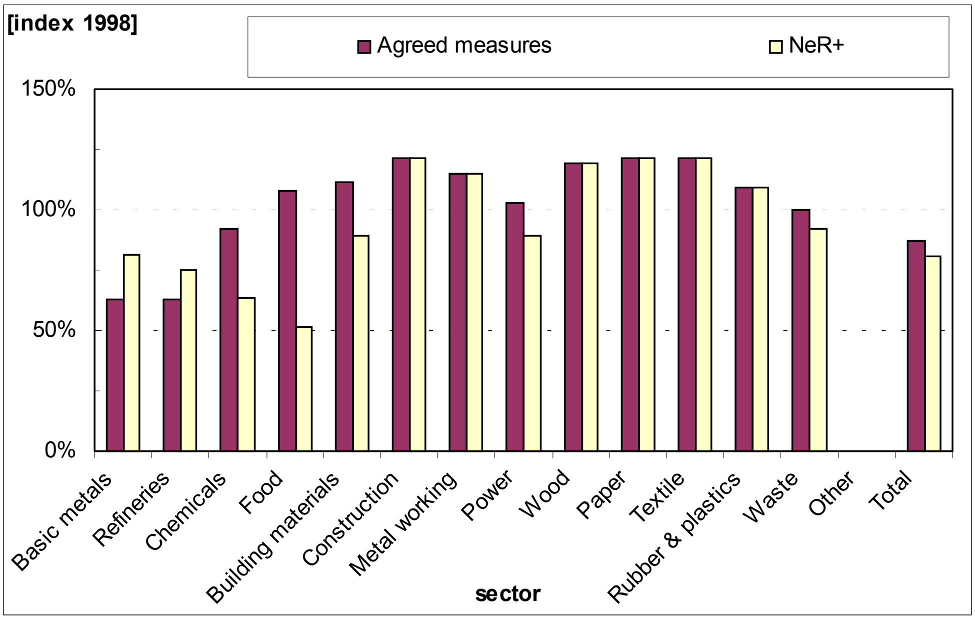

Figure 5.2 *PM_{10} emissions by sector in 2010 according the GC scenario for the cases Agreed measures and for NeR+ policies.*

The case Agreed measures presents the measures intended by several sectors as surveyed for the ‘Milieuverkenningen 5’. It concerns plans for the Basic metals, Food and Refineries. The latter have agreed upon upgrading their firing to natural gas quality. These measures are following the cost-effective case for the largest part of the reduction. Therefore, these intended measures will costs less. Again, a NeR+ will not add substantial cost-effective reduction to these agreed measures.

The agreed measures will reduce emissions with approximately 5000 ton or almost 25% of the 2010 reference emissions. This leads in 2010 to a decrease of PM_{10} emissions of 12% compared to the level of 1998 emissions[1].

To illustrate to which extend the different sectors conduct efforts, figure 5.2 presents the projected PM_{10} emission by sector for the two cases Agreed measures and NeR+. Here it is shown that measures in both cases are primarily taken in the high emitting sectors on the left hand of the graph. However, the agreed measures are allocated more to the two largest emitters Basic metals and refineries, while the NeR+ case requires also reductions in Food, Chemicals and to some extend Building materials, Power generation and Waste incineration.

At these relatively moderate reductions of PM, it is not expected that the reduction switches between sectors lead to major differences in $PM_{2.5}$ reductions and emissions (although the shares of $PM_{2.5}$ in PM_{10} are somewhat different in the sectors mentioned).

That the measures in these sectors are more expensive is illustrated in figure 5.3 that presents the annual costs by sector in million €. The column on the right, presenting the total costs, indicate that the costs of Agreed measures is 40 million € and those of NeR+ 200 million €. The previous figures indicated that the reduction is in both cases in order of 10% reduction with respect to 1998 PM_{10} emissions.

The costs in the sectors Refineries, Chemicals, Food and Building materials are indeed higher in the NeR+ case compared with the Agreed measures case. But how high are these costs? To show the burden for the sectors, the annual costs are expressed as a percentage of the Value Added of 1998 in figure 5.4. The Value Added is the value that is added to the resource materials by producing a product. Within a company, this value is created by making investments in production facilities and labour costs. Also a margin for profit has to be accounted for.

In figure 5.4, some sectors have to make annual costs up to 2% of the Value Added, which is considerable. In the NeR+ case, the Refineries and Building sector take the burden. According to the agreed measures, the sector Basic metals takes the highest burden. This points out that cost-effectiveness can lead to action and high costs in one sector, while others do nothing.

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[1] This is somewhat higher than in previous projections made by RIVM due to an outdated assumption on an aluminium plant.

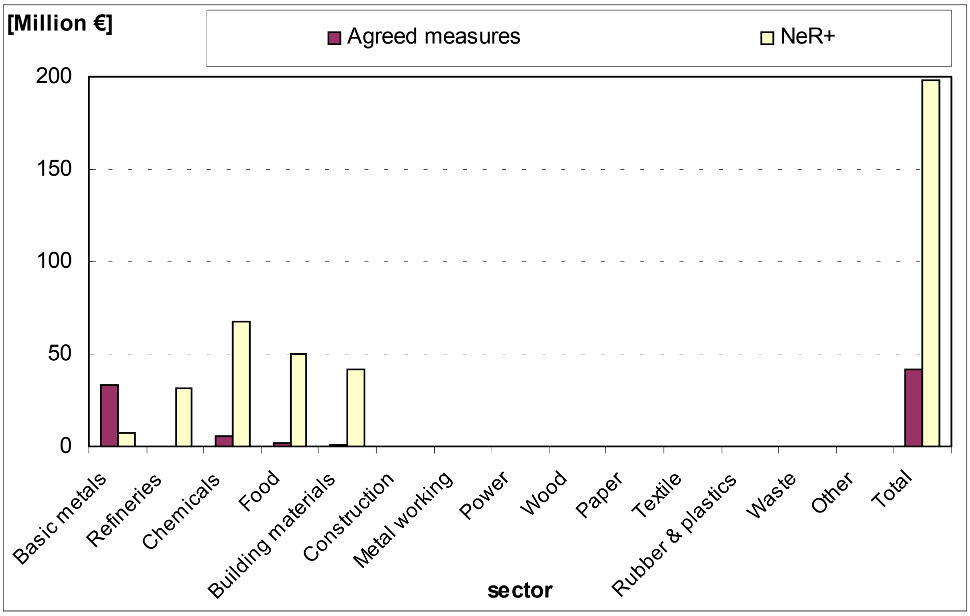

Figure 5.3 Annual PM_{10} reduction costs in million € by sector in 2010 according the GC scenario for the cases Agreed measures and for NeR+ policies.

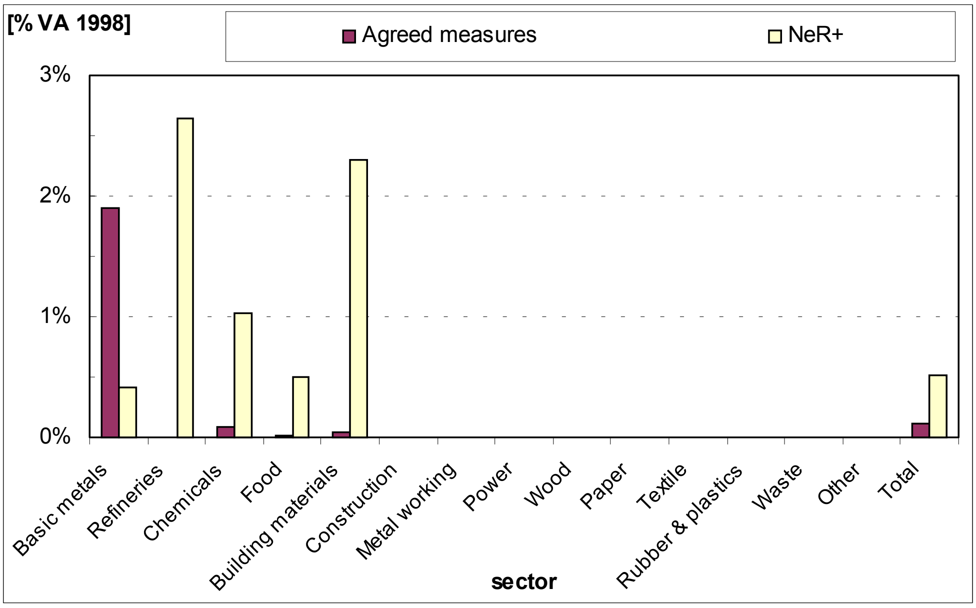

Figure 5.4 Annual PM_{10} reduction costs expressed as % of the 1998 value added by sector in 2010 according the GC scenario for the cases Agreed measures and for NeR+ policies.

This aspect of fairness (‘who takes the burden?’) has to be addressed by accompanying measures, for instance an emission reduction fund or a system of tradable emission permits. However, these measures have costs itself, so called transaction costs. Making these transaction costs is only worthwhile if the sector differences in costs are high and an increase in cost-effectiveness can be reached only by accompanying measures such as a fund or permits. This could be the case if more severe PM reductions are being analysed.

5.1.2 EU policies

On a European scale, Reference Documents on Best Available Techniques (BREF's) are under development by the European Integrated Pollution Prevention and Control (IPPC) Bureau. These BREF documents reflect the information exchange carried out according to Article 16 (2) of Council Directive 96/61/EC. They include sections on applied processes and techniques, present emission and consumption levels, techniques to consider in the determination of Best Available Technologies.

In table 5.1 we have compared the guidelines according to national NeR/BEES with the information in BREF documents for new installations for the branches of industry for which BREF-documents are in a final stage. Note that these documents are not available for the majority of sectors.

As can be seen from table 5.1 most concentration levels according to NeR/BEES are stricter than in the BREF. Only for the sinterstrand in the iron and steel industry the concentration in BREF is lower but it is expected that in short time NeR will be lowered to at least the BREF level because recently the emission concentration in The Netherlands is already under this level (agreements for 35 mg/m^3 have been made already). Also in the non-ferrous industry the concentration level is lower in BREF.

For all other sectors where BREF documents are available, the plants following the NeR and BEES directives are already in accordance with the BREF guidelines.

Table 5.1 Comparison of concentration levels between NeR and BEES directives and EU BREF guidelines (new installations).

Industrial sector	**Process**	**Reduction technique ***	**Dust concentration / emission**		
			NeR [mg/m^3]	**BREF [mg/m^3]**	**[kg/ton pr.]**
Cement	Cement production	FF (ESP)	10	10-50	
	. Kiln systems	FF (ESP)	10	10-50	
	. Clinker cooler	FF (ESP)	10	10-50	
	. Cement mills	FF (ESP)	10	10-50	
Iron and Steel	Sinter strand	Advanced ESP	100	50	
	. idem	ESP + HES	100	50	
	. idem	ESP + lime + FF	10	10-20	
	Pelletisation				< 0.1
	. Grinding mills	ESP	10	< 50	
	. Drying / induration	FF (wet scrubber)	10	< 20	
	Coke oven plant				
	. Charging / pushing	collection + FF	10	< 30	< 0.01
	. Quenching	wet scrubber	<0.06 kg/t		< 0.05
	Blast furnace				
	. Furnace gases	HES (wet ESP)	25	< 10	
	. Cast house	collection + FF (ESP)	effic. >99%	1-15	
	Basic Oxygen Steel	collection + FF (ESP)	10	10-15/20-30	
	. Fugitive		< 5 g/ton		5-15 g/ton
	Electric Steel making	collection + FF	10	5-15	
Glass	Melting	FF or ESP	10 / 25	<10 -20	< 0.1
	. Container / Flat glass	FF or ESP	10 / 25	5-30	< 0.1
	. Fibre glass	FF or ESP	10 / 25	5-30	< 0.14
	. Glass wool	FF or ESP	10 / 25	5-30	< 0.1
Ferrous Metals	Hot rolling				
	. Dry dust	enclosure + FF	10	<5-20	
	. Wet fumes	enclosure + ESP	25	<10-50	
	Cold rolling				
	. Decoiling / levelling / welding	collection + FF	10	<5-20	
Non Ferrous	Electrode baking	dry aluminium + FF	10	1-5	
	Other sources	collection + FF	10	1-5	
Lime	Calcining of lime	FF / ESP	10 / 25	<5-20	0.1-0.2
	Hydrating	FF / LES / HES	10 / 25	<5-20	0.02
	Grinding and milling	FF	10		0.03

* Explanation:

FF = fabric filter;

ESP = electrostatic precipitator;

LES = low energy scrubber;

HES = high energy scrubber.

5.2 Additional emission reduction

To explore possibilities for further reductions, figure 5.5 presents the same marginal reduction cost curve as was presented in figure 5.1, but this time the graph is cut-off at the costs of 350 € per kg reduction. At these costs, the PM_{10} emission reduction potential reaches up to 80% of the reference emission of 21.2 kton as indicated by the bold vertical line (or 75% reduction of the 1998 emission level). This is in fact the technical feasible reduction. For comparison reasons the two cases on policies in pipelines have been presented with the case of Cost-effective reduction.

As has been already stated, this cost curve is calculated for the GC scenario. The Cost-effective reduction case has also been calculated for the EC scenario and is presented in Appendix B. The conclusions from the comparison is that the differences are limited and certainly within the ranges of uncertainty of the emission and reduction cost estimations.

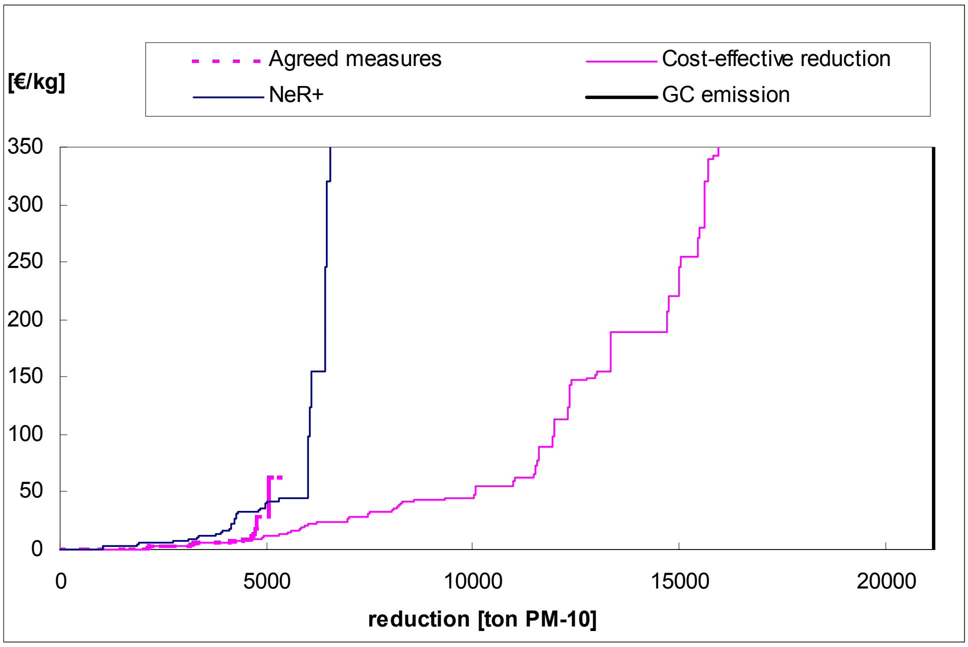

Figure 5.5 *Marginal costs curves for PM_{10} emission reduction by Dutch industrial sources in 2010 in three cases presented with reference to the GC emission projection without additional measures (frozen technology: solid bold line at 21200 ton).*

The slope of the marginal cost-curve is weak up to approximately 50% reduction or 11 kton PM_{10} emission. Up to this point, reductions can be reached at marginal costs up to 60 € per kg reduction. This is a factor 25 higher than the current cut-off level in the NeR. Figure 5.6 shows the underlying PM_{10} reduction by sector for this case, together with the NeR+ and the Technical feasible cases. The bar on the right in the graph presents the total emission. Again, here the 75% reduction with respect to the 1998 emission can be viewed for the Technical feasible case.

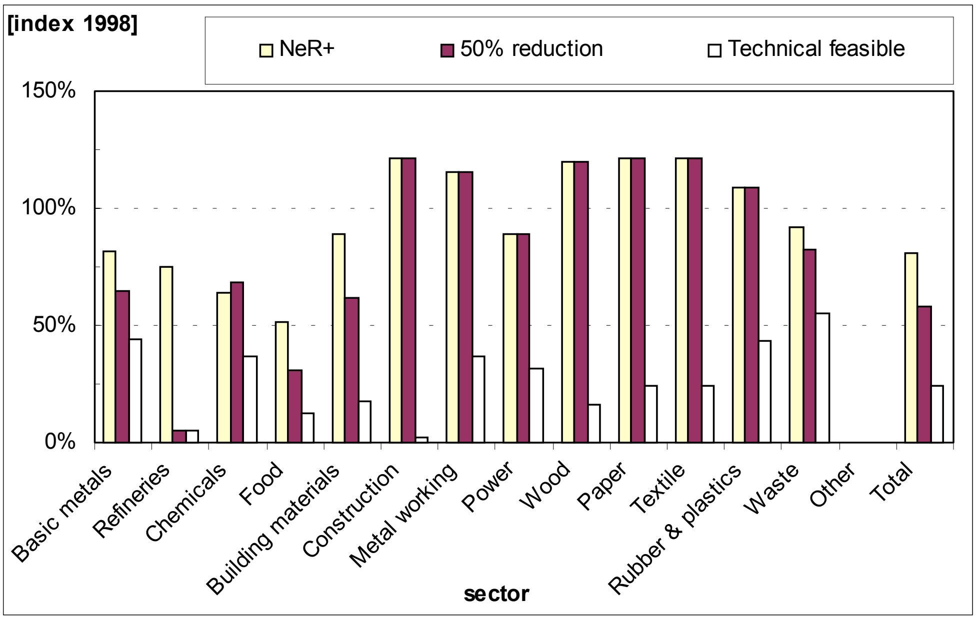

Figure 5.6 PM_{10} emission by sector in 2010 according the GC scenario for the cases of NeR+ policies, 50% cost-effective emission reduction and the maximum feasible reduction.

As has already been indicated by the analysis in the previous section on policies in pipeline, the NeR+ reduction level is the level of cost-effective reduction for the sectors Basic metals and Chemicals if 50% reduction has to be reached. Only in the Refineries, Food and to some extend the Building materials is more cost-effective potential available. Especially if the Refineries are taking severe reduction measures, the $PM_{2.5}$ emissions will be reduced even stronger than the PM_{10} emissions. On average, $PM_{2.5}$ shares are relatively high in the five heavy emitting sectors, indicating that PM_{10} policies will be relatively more than equally effective for $PM_{2.5}$ in most cases.

Another maybe not surprising but nevertheless important conclusion is that all sectors besides the five high emitting sectors (on the left of the graph) not reduce their emissions in a cost-effective strategy to reduce national emissions with 50%. Obviously, the options are technical feasible but the costs are apparently higher in these sectors where PM concentrations of gas flows are lower, gas flows are smaller and flowing at less hours in the year. A striking example of this observation is the Construction sector that has the highest growth, the largest technical reduction potential and implements no options if the rule of national cost-effectiveness is being followed.

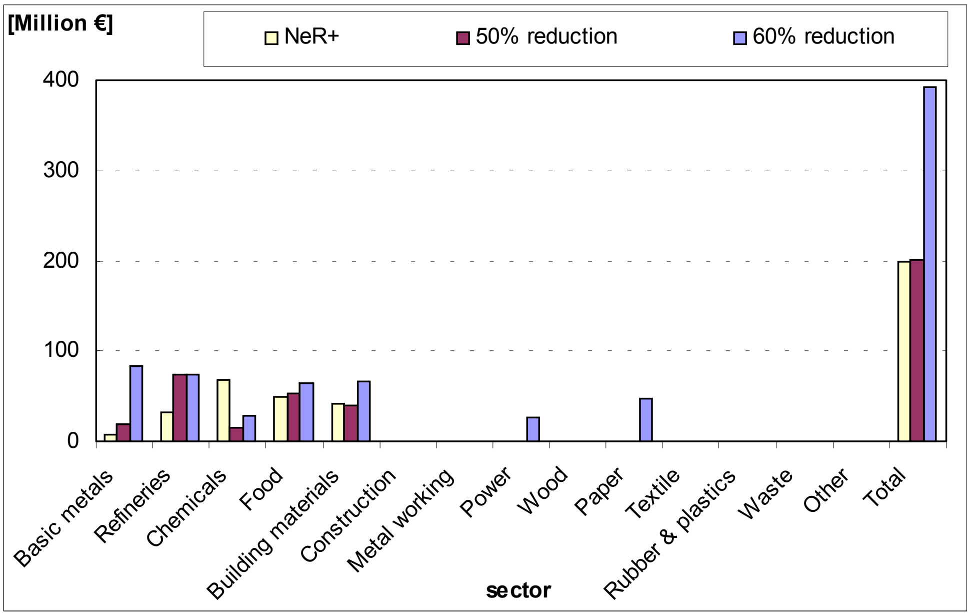

Figure 5.7 Annual PM_{10} reduction costs in million € by sector in 2010 according to the GC scenario for the cases of NeR+ policies, 50% cost-effective emission reduction and 60% cost-effective emission reduction.

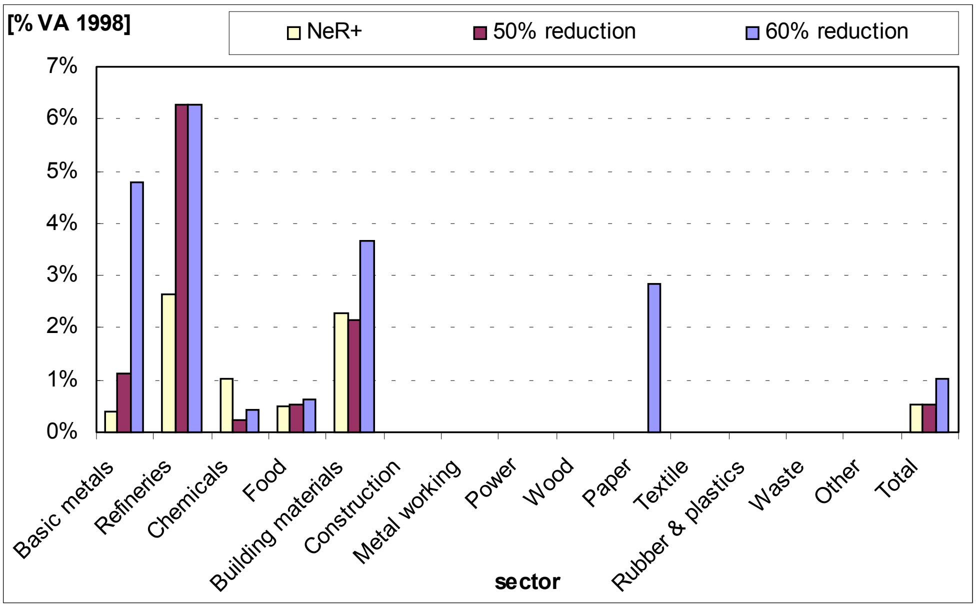

Figure 5.8 Annual PM_{10} reduction costs expressed in 1998 value added by sector in 2010 according to the GC scenario for the cases of NeR+ policies, 50% and 60% cost-effective emission reduction.

Figure 5.7 presents the total reduction costs by sector. It shows (right cluster of bars) that the total costs of reaching 50% reduction cost-effectively are the same as implementing the NeR+, reaching approximately 3/5 of the reduction of the 50%

reduction case. However, we can also see that cost-effectiveness can not solve it all, because an additional 10% reduction up to 60% reduction doubles the total costs to 400 million €. This is due to the sudden, steep increase in the marginal reduction costs at reductions higher than 50%, as had been indicated already when discussing figure 5.5. Then also sectors with lower emissions such as Paper and Power generation have to take expensive measures.

The burden of the costs for each sector are presented in figure 5.8 where the total costs are expressed as a percentage of the 1998 Value Added. Obviously, sectors as the Refineries, Basic metals, Building materials and Paper are taking a heavy burden in case that 60% reduction is strived for in a cost-effective manner on a national scale. However, also the 50% cost-effective case is not equally distributing the burdens. In that case, the refineries take the burden. It is interesting to see that compared with the case of Agreed measures, the Basic metals is doing less.

The main conclusion on the economic feasibility of reductions further than the present policies in pipeline is that the cost-effective options are mainly present in the five heavy emitting sectors, which cannot carry the burden of the reduction costs (up to 7% of the Value Added) if competing companies in other countries do not have similar obligations. The burden for the total industry is limited (0.5% of the Value Added of industrial sources) but, if the polluter pays principle is respected, this type of emission targets can only be implemented at international level in order to secure international competitiveness of industrial sectors.

5.3 Some policy aspects

5.3.1 Cost-effectiveness, concentration standards and particle size

In the previous section, the possibilities for emission reductions of 50% or more have been presented. It concerned reduction options that were selected on the basis of cost-effectiveness, resulting in a least-cost reduction strategy for PM_{10} emissions of all industrial sources in the Netherlands. Therefore, this is the most optimistic case in terms of PM_{10} reduction costs. Or, looking from a different perspective, this approach assumes that market based policy instruments such as emission taxes or tradable permits will be effectively used to implement particulate emission reduction.

In this paragraph, the analysis is extended with two additional policy aspects, each addressed in a separate policy case. One case applies emission concentration standards and the other addresses cost-effective reduction of emissions with a relatively small particle size, viz. $PM_{2.5}$.

The concentration standard limits the emission at a certain amount of mg per m^3 of waste gas and is applied for all sectors. In a sense, a generic concentration standard can be viewed as a fair allocation principle treating each sector and company equal. This case gives an indication of the variety of the costs if a less cost-effective solution is reached.

Next to PM_{10}, $PM_{2.5}$ is more and more being mentioned as a possible handle for policies. This is not the place to discuss the pro's and con's of using PM_{10} and $PM_{2.5}$ as an indicator or handle for air quality and health policy. However, we will analyse the impacts on overall and sector PM-reductions and abatement costs of either using PM_{10} or $PM_{2.5}$ as a basis for designing reduction policies. This is done under the assumption that PM_{10} and $PM_{2.5}$ emissions are being removed equally efficient by abatement technologies, since the present abatement technologies have all a reduction efficiency for $PM_{2.5}$ of more than 95% of the PM_{10} reduction efficiency (see section 3. Emission reduction technologies).

5.3.2 Reduction costs

Both the cases of PM_{10} concentration standards and cost-effective reduction of $PM_{2.5}$ are presented next to the case of cost-effective reduction of PM_{10} in figure 5.9. This figure presents the total reduction costs in 2010 as a function of the total reduction expressed as a percentage of the reference emission ('frozen technology' projection of the Global Competition scenario). In the cases of PM_{10} it concerns the share of PM_{10} emissions, for $PM_{2.5}$ it is the share of $PM_{2.5}$ emissions. For the case using concentration standards, the concentration limits are indicated in the graph as well. The concentrations are not exactly linearly correlated to the emissions since some sources have (already) lower concentrations of waste gases (at low reduction rates) or for some sources it is technically infeasible to reach the concentration standard (at higher reduction rates).

Figure 5.9 clearly illustrates that, at reduction rates of 30% to 65%, the costs of emission concentration standards are approximately twice as high as the costs of a cost-effective reduction strategy. In contrast, reductions of $PM_{2.5}$ in the same range are possible at half the costs to reduce PM_{10}. At the maximum feasible reduction rates of almost 80%, all three cases in the graph have the same costs, since all options available in the database are being applied. This point may occur in reality at higher reduction rates when all existing options are being implemented.

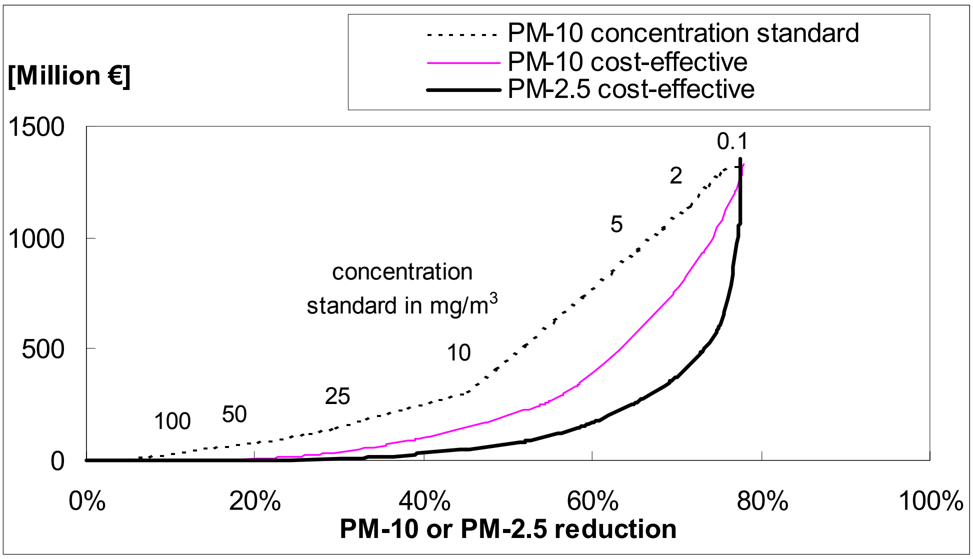

Figure 5.9 *Total annual reduction costs as a function of the total reduction-% (with respect to the 'frozen technology' reference in the GC scenario) by Dutch industrial sources in 2010 in three cases, viz. a cost-effective* $PM_{2.5}$ *reduction strategy, a cost-effective* PM_{10} *reduction strategy and the application of a general* PM_{10} *concentration standard (indicated in the graph).*

The concentration standard results in higher costs since all sectors are obliged to reduce emissions, also the ones with higher unit costs. The $PM_{2.5}$ reduction case has lower costs due to a combination of two things. First, the $PM_{2.5}$ reduction concerns relatively low reduction volumes, which decreases the costs. Second, cost-effective $PM_{2.5}$ reduction focuses on sources with high $PM_{2.5}$ fractions, which limits the unit costs. For the sources up to 70% reduction, $PM_{2.5}$ reduction costs are approximately twice as low as for PM_{10}.

This is illustrated once more in figure 5.10 that presents the marginal reduction costs for PM_{10} and $PM_{2.5}$ as a function of the emission reduction share. The marginal cost curves in terms of reduction-% are similar for the largest part of the reduction trajectory. However, the overall emission of PM_{10} is approximately twice as large as the $PM_{2.5}$ emission, hence resulting in total reduction costs twice as high for PM_{10}. In general, it is expected that these cost curves for PM_{10} and $PM_{2.5}$ will lie close to each other for the first part of the reduction trajectory, but it is also very dependent on individual options.

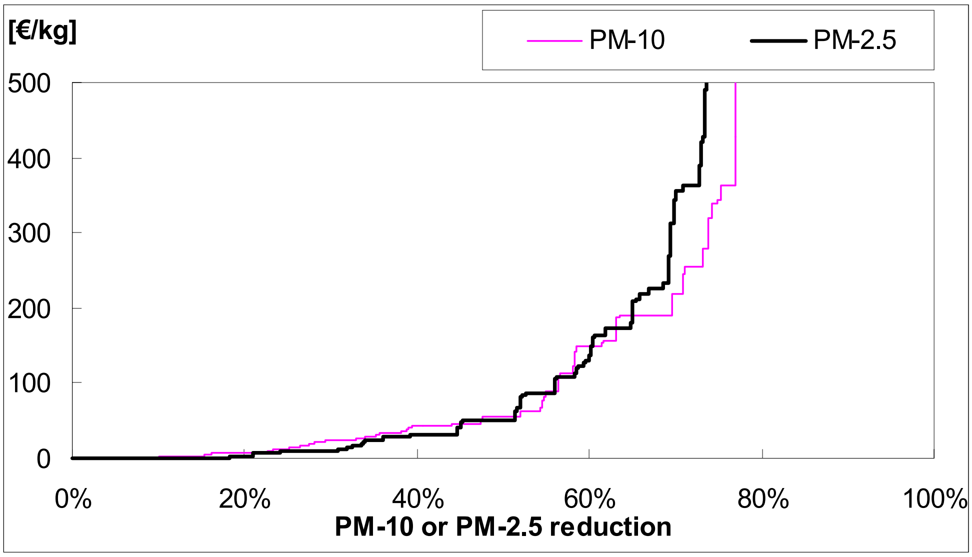

Figure 5.10 Marginal PM_{10} and $PM_{2.5}$ reduction costs as a function of the total reduction-% PM_{10} or $PM_{2.5}$ respectively (with respect to the 'frozen technology' reference scenario) by Dutch industrial sources in 2010 according to the GC scenario.

5.3.3 Connection of PM_{10} and $PM_{2.5}$ reduction

What will be, besides the aspect of costs, the consequence of choosing PM_{10} or $PM_{2.5}$ as a basis for reduction policies? PM_{10} includes also all $PM_{2.5}$, while $PM_{2.5}$ excludes all larger particles within PM_{10}. ($2.5\ \mu m < d < 10\ \mu m$). Reduction of PM_{10} leads also to $PM_{2.5}$ reduction, depending on the $PM_{2.5}$ fraction. Reduction of $PM_{2.5}$ can also lead to reduction of larger particles, also depending on the $PM_{2.5}$ fraction.

In a cost-effective PM_{10} reduction strategy, the first attractive PM_{10} reduction contains high fractions of $PM_{2.5}$ (relative to the average $PM_{2.5}$ fraction) resulting in relatively high reduction shares for $PM_{2.5}$. This is illustrated in figure 5.11 where the first 50% PM_{10} reduction leads to 60% $PM_{2.5}$ reduction. It is a matter of coincidence that the sectors with the cost-effective PM_{10} reductions operate processes having PM emissions with relatively high fractions of $PM_{2.5}$. It is rooted in the combination of physical properties of large scale production processes and the economic aspects of the abatement options applied to these processes. This is probably a general phenomena occurring in more European countries, although its importance is dependent on the exact dimensions of the underlying processes and sector structures. It is concluded that a reduction policy in terms of PM_{10} is a general approach with complete coverage of all particles, which is also (at least as) effective for $PM_{2.5}$, but is due to the large volumes also expensive.

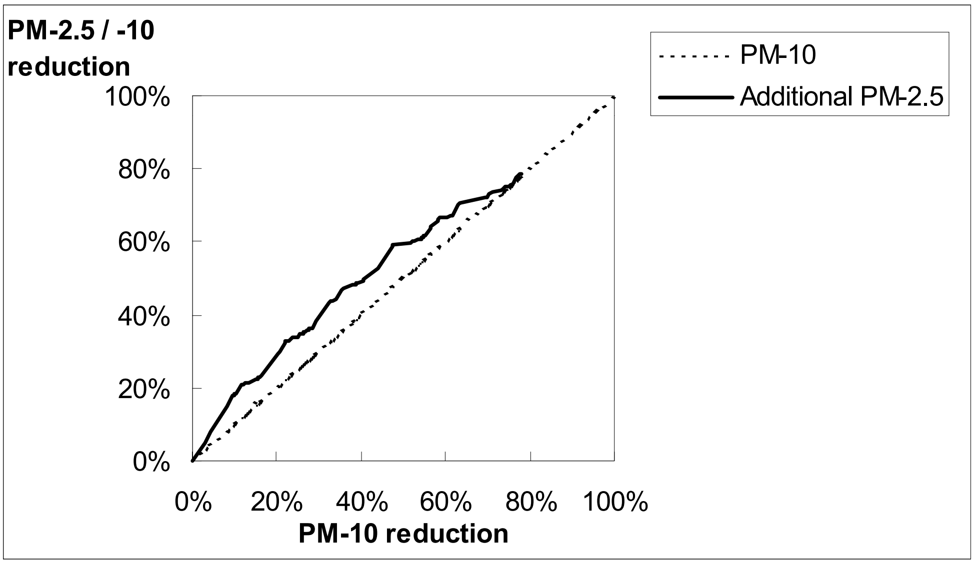

Figure 5.11 Additional $PM_{2.5}$ emission reduction as a result of cost-effective PM_{10} reduction policies presented as a function of the level of PM_{10} reduction.

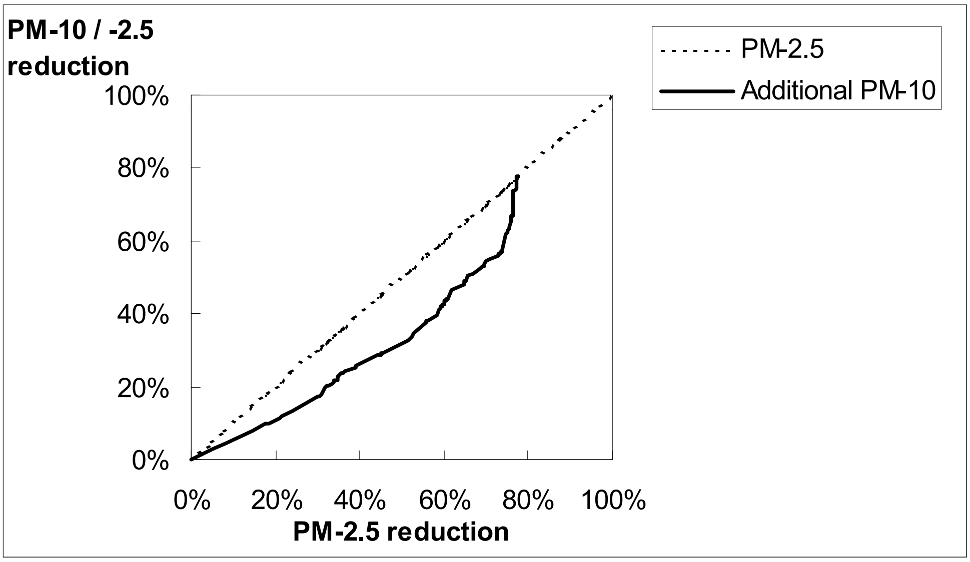

Figure 5.12 Additional PM_{10} emission reduction as a result of cost-effective $PM_{2.5}$ reduction policies presented as a function of the level of $PM_{2.5}$ reduction.

Vice versa, $PM_{2.5}$ reduction always leads to PM_{10} reduction as well since $PM_{2.5}$ falls within the category of PM_{10}, and can lead to even larger PM_{10} reductions if the $PM_{2.5}$ fraction is lower than 1. However, a cost-effective strategy of $PM_{2.5}$ focuses on reductions with high $PM_{2.5}$ fractions, leading to relatively low additional PM_{10} reduction shares (compared to the average $PM_{2.5}$ fraction). In figure 5.12, the first 50% $PM_{2.5}$ reduction leads to only 30% PM_{10} reduction due to the difference between the $PM_{2.5}$ fraction in the cost-effective reduction and the average PM_{10} emission (more than 80% versus 50% respectively).

Conclusion is that a more specific cost-effective reduction policy formulated in terms of $PM_{2.5}$ is approximately 50% cheaper but results in much lower reductions shares for PM_{10} (compared to the share of $PM_{2.5}$ reduction). This approach is most suited for a situation where particles with a size larger than 2.5 µm are considered as less relevant for health since these are reduced much less than $PM_{2.5}$.

5.3.4 Sector contributions

Figure 5.13 illustrates that if cost-effective $PM_{2.5}$ abatement is pursued, PM_{10} emission reduction in the five high emitting sectors becomes less attractive, particularly in the sectors food and building materials. It is shown clearly that the total reduction volume of PM_{10} is smaller in the case of 50% $PM_{2.5}$ reduction (compared with the 50% reduction of PM_{10}). If a concentration standard of 9 mg/m^3 waste gas is being applied (leading to approximately 50% PM_{10} emission reduction), sectors with smaller emission flows such as Construction, Metal working, Paper, Textile and Power have to reduce their emissions as well.

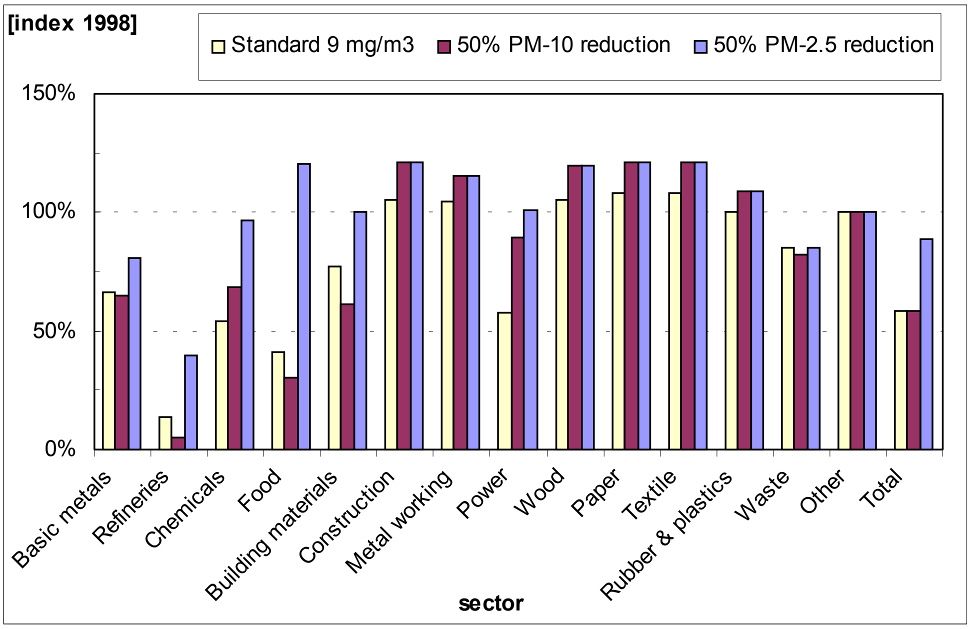

Figure 5.13 PM_{10} emissions by sector in 2010 according the GC scenario for the cases of a concentration standard of 9 mg/m^3, 50% cost-effective PM_{10} emission reduction and 50% cost-effective $PM_{2.5}$ emission reduction.

6. Conclusions

Five sectors are the main source of industrial PM_{10} and $PM_{2.5}$ emissions
PM_{10} emissions from industrial sources in the Netherlands were 18 kton or one third of the national total in 1998. $PM_{2.5}$ emissions were estimated to be 8.8 kton or a quarter of the national total in 1998. This is 16% lower compared to previous estimations by RIVM. Especially the fractions of Food and Building materials have been halved due to the calculation at a more detailed source (process) level.

Both PM_{10} and $PM_{2.5}$ emissions are forecasted according to the Global Competition scenario to grow moderately with 17% up to respectively 21.2 and 9.6 kton in 2010, assuming no change in technologies. Since $PM_{2.5}$ emissions are not equally distributed over sectors and sectors grow with different rates, developments of reference $PM_{2.5}$ emissions could differ from PM_{10} emissions. However, this is not the case since the differentiation in growth by sector is rather limited. Growth projections for the European Coordination scenario are with 11% quite similar to the GC scenario and therefore are not presented separately.

The five highest emitting sectors are Basic metals, Refineries, Chemicals, Food and Building materials, together being responsible for 80% of the PM_{10} and almost 90% of the $PM_{2.5}$ emissions from industrial sources.

The sector Commerce and Public services emitted another 2.5 kton PM_{10} and 0.3 kton $PM_{2.5}$ in 1998. The further analysis included ***not*** the Commerce & Public services since the data on reduction options on materials handling were considered to be too uncertain to estimate the reduction potentials and costs for the sector. Nonetheless, materials handling options have been included for industrial sources.

Agreed measures and EU policies in pipeline reduce 2010 emissions moderately
The presently agreed measures will reduce 2010 PM_{10} emissions of industrial sources with approximately 5 kton or more than 25% of the 1998 emissions. This leads to PM_{10} emissions of 15.8 kton, 12% below the level of 1998 emissions. The annual costs are estimated to be around 40 million €. One has to bear in mind that in some cases, measures are not only taken for the purpose of PM control.

The Dutch directives NeR and BEES result in an emission level 20% below 1998 emissions if the present clause on maximum costs of 2.3 € per kg is increased to a higher level of for instance 30 € per kg. The costs are 200 million €.

The plants following the NeR and BEES directives are already in accordance with the EU Reference Documents on Best Available Techniques (BREF) for all sectors where these are available, except for the non-ferrous industry and the sinter strand of the iron & steel (but the latter has already implemented to the BREF levels).

Further reduction is expensive…

Approximately 50% reduction or 11 kton PM_{10} reduction can be achieved cost-effectively at marginal costs up to 60 € per kg reduction. Cost-effective reduction options are found in the five high emitting sectors only. The total annual costs of reaching 50% reduction cost-effectively are 200 million €, which is equal to implementing the high costs NeR options, that reaches only 30% reduction. Total annual costs to reduce 60% of the reference emissions, which is equal to an emission level of half the 1998 emissions, are 400 million €. This is in the same order of magnitude as the costs of reaching the Dutch target for greenhouse gases as agreed in the Kyoto protocol [1].

The technical PM reduction potential reaches up to 80% but the options to reach more severe reductions are much more expensive. These options are present in the sectors that are not within the group of five high emitting sectors. In these sectors, the PM unit costs are higher due to lower concentrations of gas flows and smaller gas flows (due to lower capacity or running hours).

Table 6.1 PM_{10} emissions and reduction costs of industrial sources in different cases according to the Global Competition scenario.

Year	**Case**	**PM_{10} emissions**		**Annual costs**
		[kton]	**[Index 1998]**	**[Million €]**
1998	Actual emission	18.0	100%	-
2010	Reference (frozen technologies)	21.2	117%	-
2010	Agreed measures	15.8	88%	40
2010	NeR+ regulation	14.6	81%	200
2010	50% cost-effective reduction	10.6	59%	200
2010	60% cost-effective reduction	8.5	47%	400
2010	Technical feasible	4.7	26%	1300

… and makes an international level playing field necessary

Dutch industries already comply with almost all EU Best Available Technologies. Further reductions can be reached at acceptable burdens for the total industry (0.5% of the Value Added of industrial sources). However, the cost-effective options are mainly present in five heavy emitting sectors. If the polluter pays principle is respected, these sectors can only carry the high burden of the reduction costs (up to 7% of the Value Added), if this type of emission targets are implemented at international level in order to secure international competitiveness of industries.

General concentration standards double the costs

At PM_{10} reduction rates of 30% to 65%, the costs of general emission concentration standards are approximately twice as high as the costs of a cost-effective PM_{10}

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[1] An annual reduction of 50 Mton CO_2 equivalent at an assumed average price of 10 € per avoided ton CO_2 equivalent will cost 500 million € per year.

reduction strategy. A general concentration standard affects also sectors with smaller emission flows such as Construction, Metal working, Paper and Textile.

Specific $PM_{2.5}$ *reduction is half as expensive as* PM_{10} *reduction*
All present abatement technologies have a reduction efficiency for $PM_{2.5}$ of more than 95% of the PM_{10} reduction efficiency. Moreover, PM_{10} policies will be relatively more than equally effective in reducing national $PM_{2.5}$ emissions. This is related to the high fraction of $PM_{2.5}$ in PM_{10} emission sources in the five heavy emitting sectors that can be abated cost-effectively. This is caused by the techno-economic properties of the abatement options on large scale production processes.

A reduction policy in terms of PM_{10} is a general approach with complete coverage of all particles, but is therefore also expensive. Vice versa, a more specific reduction policy formulated in terms of $PM_{2.5}$ results in much lower reductions shares for PM_{10} (compared to the share of $PM_{2.5}$ reduction). The advantage of this focus on $PM_{2.5}$ is that smaller quantities have to be mitigated, resulting in approximately halved costs (depending on the average $PM_{2.5}$ fraction of PM_{10}). This approach is most suited for a situation where particles with a size larger than 2.5 μm are considered as less relevant for health since these are reduced much less than $PM_{2.5}$.

Improved exchange of information with companies is needed
The companies report PM in terms of Total Suspended Particulates to the Pollutant Emission Register. $PM_{2.5}$ is generally not known in the industry. Even the calculation to PM_{10} gives often difficulties.

The costs of reduction options can be influenced highly by local circumstances such as existing technologies, building types, space etc. The information on the company situation in general and the installed abatement technologies in particular is since 1995 not monitored in the Dutch Pollutant Emission Register. The Environmental Reports of the companies are not reporting systematically on these subjects. Also, the failure of abatement equipment, which can result in high annual emissions within a few days, are not reported and monitored.

This indicates that the present estimations of emissions, but in particular of reduction potentials and costs, are still surrounded with considerable uncertainty. This uncertainty can only be decreased by enhanced communication, data exchange and cooperation between the companies, the relevant ministries and the environmental institutes involved in monitoring and policy support.

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8. Authentication

Name and address of the principal:

Novem
Ministry of VROM

Names and functions of the cooperators:

A.K. van Harmelen
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A.J.H. Visschedijk

Names and establishments to which part of the research was put out to contract:

-

Date upon which, or period in which, the research took place:

April 2001 to August 2002

Signature:	Approved by:
A.K. van Harmelen Projectleader	Ir. H.S. Buijtenhek Head of department

Appendix A Growth factors and $PM_{2.5}$ fractions

Table A.1 Growth by sector from the scenario Global Competition for the years 2005 and 2010 specified as an index of the year 1998.

SBI code	Sector	Growth category	Growth [index 1998]	
			2005	**2010**
17	Textile	Industry average	1.12	1.21
21	Paper	Physical production paper	1.11	1.20
27	Metal	Physical growth ferrous	1.06	1.08
28	Metal products	Physical growth ferrous	1.06	1.08
29	Machinery	Physical growth ferrous	1.06	1.08
45	Building	Physical production building materials	1.10	1.17
251	Rubber	Industry average	1.12	1.21
264	Crude ceramics	Physical production building materials	1.10	1.17
2742	Aluminium	Physical growth non-ferrous aluminium	0.99	0.98
2743	Primary Zinc	Physical growth non-ferrous zinc	1.13	1.20
2744	Secondary Copper	Physical growth non-ferrous others	1.15	1.27
15400	Food	Consumption food	1.12	1.21
20/361	Wood & furniture	Industry average	1.12	1.21
23201	Refining	Physical growth refineries	1.12	1.24
24100	Chemical	Physical production petrochemicals	1.19	1.35
24130	Inorganic chemical	Physical production inorganic chemicals	1.20	1.36
24130	Soot production	Industry average	1.12	1.21
24141	Phenol production	Physical production petrochemicals	1.19	1.35
24141	Polystyrene production	Physical production basic chemicals	1.20	1.36
24142	Catalyst production	Physical production petrochemicals	1.19	1.35
24142	Salt production	Physical production inorganic chemicals	1.20	1.36
24142	Fertiliser	Physical production fertiliser	1.03	1.05
24142	PVC production	Physical production petrochemicals	1.19	1.35
24310	Active carbon production	Physical production basic chemicals	1.20	1.36
26110	Glass plates	Physical production building materials	1.10	1.17
261/2/3	Fine ceramics / glass	Physical production building materials	1.10	1.17
26510	Cement	Physical production building materials	1.09	1.16
26620	Building materials	Physical production building materials	1.10	1.17
27100	Steel production (Oxy-steel)	Physical growth oxy-steel	1.06	1.07
27100	Other basic metal	Physical growth steel	1.06	1.10
27510	Casting iron & steel	Physical growth ferrous	1.06	1.08
40001	Power generation	Electricity production	0.94	1.02
90003	Waste incineration	Constant	1.00	1.00
90003	Waste treatment	Physical production building materials	1.10	1.17
90003	Dismantling	Physical production building materials	1.10	1.17
90003	Infrastructure	Physical production building materials	1.10	1.17

Table A.2 *$PM_{2.5}$ presented as a fraction of PM_{10} by sector in the Netherland in 1998 (resulting from estimations at process level).*

Sector	**$PM_{2.5}$ [fraction of PM_{10}]**
Basic metals	0.54
Refineries	0.82
Chemicals	0.55
Food	0.17
Building materials	0.36
Construction	0.10
Metal working	0.62
Power	0.64
Wood	0.10
Paper	0.10
Textile	0.10
Rubber & plastics	0.10
Waste	0.97
Other sources	0.60
Commerce & services	0.13
Total industrial sources	0.49
Total incl. Commerce & services	0.44

Appendix B Scenario comparison

Table B.1. PM_{10} and $PM_{2.5}$ emissions according to the Global Competition scenario (frozen technology).

Sector	**PM_{10} 1998**	**PM_{10} GC 2005**	**PM_{10} GC 2010**	**$PM_{2.5}$ 1998**	**$PM_{2.5}$ GC 2005**	**$PM_{2.5}$ GC 2010**
Basic metals	4.6	4.8	4.9	2.5	2.6	2.6
Refineries	3.4	3.8	4.2	2.8	3.1	3.5
Chemicals	2.4	2.8	3.1	1.3	1.5	1.7
Food	2.3	2.6	2.8	.4	.4	.5
Building materials	1.8	2.0	2.2	.7	.7	.8
Construction	1.1	1.2	1.3	.1	.1	.1
Metal working	.5	.6	.6	.3	.4	.4
Power	.5	.5	.6	.3	.3	.4
Wood	.4	.5	.5	.0	.0	.0
Paper	.4	.4	.5	.0	.0	.0
Textile	.1	.1	.1	.0	.0	.0
Rubber & plastics	.1	.1	.1	.0	.0	.0
Waste	.0	.0	.0	.0	.0	.0
Other sources	.4	.4	.4	.2	.2	.2
Total industrial sources	**18.0**	**19.7**	**21.2**	**8.8**	**9.6**	**10.3**
Commerce & services	2.5	2.6	2.7	.3	.3	.3
Total incl. Comm. & serv.	**20.5**	**22.3**	**23.8**	**9.1**	**9.9**	**10.7**

Table B.2. PM_{10} and $PM_{2.5}$ emissions according to the European Coordination scenario (frozen technology).

Sector	**PM_{10} 1998**	**PM_{10} EC 2005**	**PM_{10} EC 2010**	**$PM_{2.5}$ 1998**	**$PM_{2.5}$ EC 2005**	**$PM_{2.5}$ EC 2010**
Basic metals	4.6	4.6	4.5	2.5	2.5	2.5
Refineries	3.4	3.6	3.8	2.8	2.9	3.1
Chemicals	2.4	2.7	3.0	1.3	1.5	1.6
Food	2.3	2.6	2.8	.4	.4	.5
Building materials	1.8	2.0	2.1	.7	.7	.8
Construction	1.1	1.2	1.3	.1	.1	.1
Metal working	.5	.6	.6	.3	.4	.4
Power	.5	.5	.4	.3	.3	.3
Wood	.4	.4	.5	.0	.0	.0
Paper	.4	.4	.5	.0	.0	.0
Textile	.1	.1	.1	.0	.0	.0
Rubber & plastics	.1	.1	.1	.0	.0	.0
Waste	.0	.0	.0	.0	.0	.0
Other sources	.4	.4	.4	.2	.2	.2
Total industrial sources	**18.0**	**19.2**	**20.0**	**8.8**	**9.3**	**9.6**
Commerce & services	2.5	2.5	2.6	.3	.3	.3
Total incl. Comm. & serv.	**20.5**	**21.7**	**22.6**	**9.1**	**9.6**	**9.9**

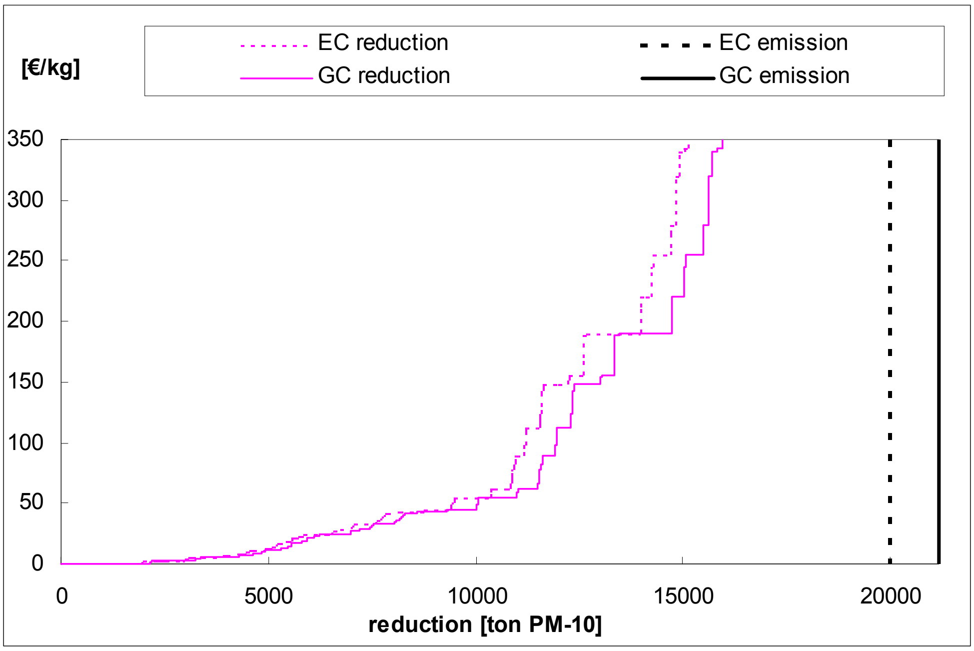

Figure B.1 *Comparison of Global Competition and European Coordination* PM_{10} *emission projection and reduction costs in 2010.*

Appendix C Reduction cost curves with and without agreed measures

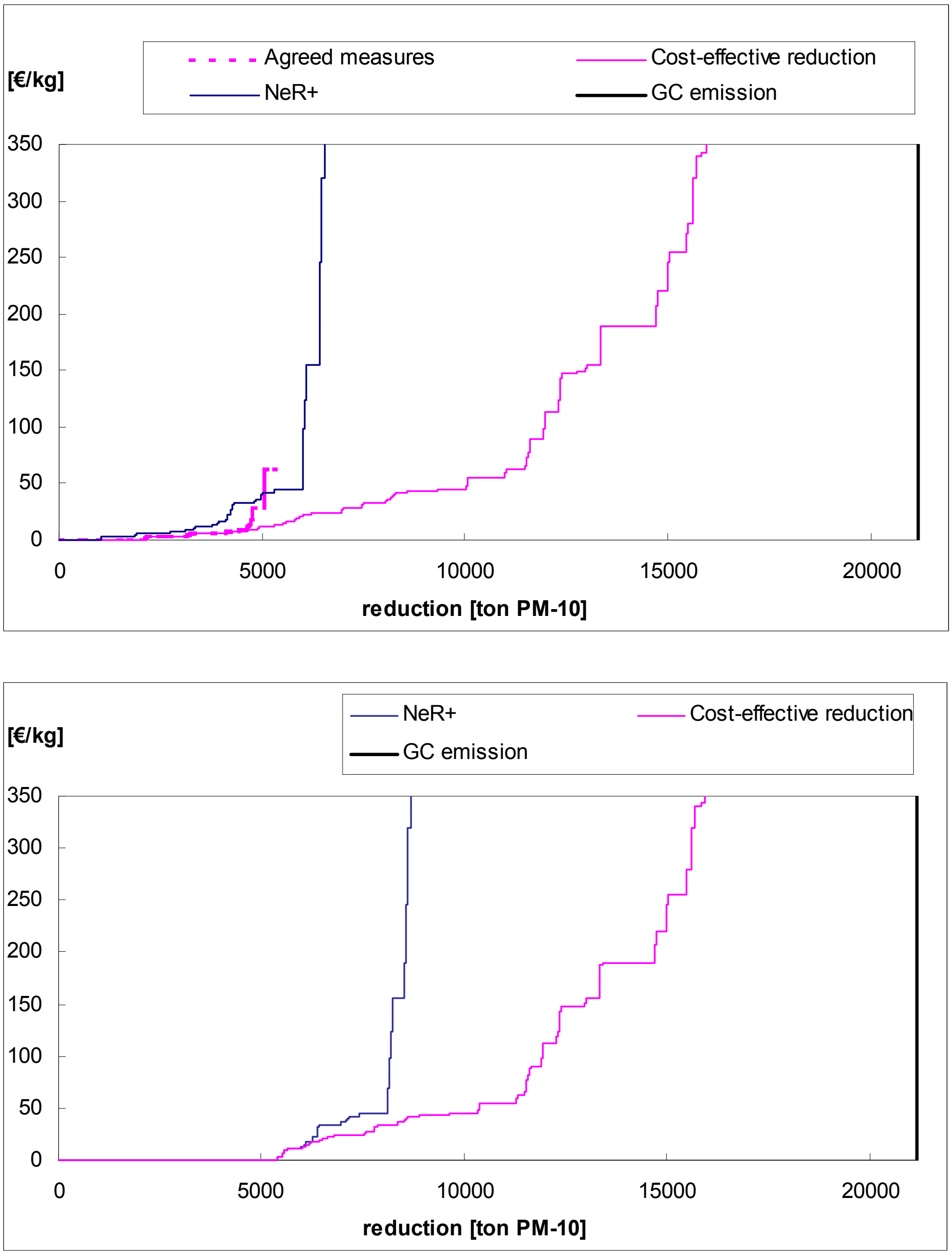

Figure C.1 *PM_{10} emission reduction costs for a Reference case excluding agreed measures (frozen technology, above) and including agreed measures (below), both according to the Global Competition scenario in 2010.*

Appendix D Branch descriptions

This appendix gives an overview of available information by branch, which served as a background for the assessment made in the report. It provides useful background information on the fine dust situation in the different industrial branches.

Before describing the branch situations, table D.1 provides a data overview per branch on PM_{10} and $PM_{2.5}$ emissions and concentrations in 1998, presently installed abatement technologies (1998) and possible future measures that might be taken and the resulting concentrations and specific costs. The technology related figures are indicative and the concentration ranges can vary substantially, since the underlying sources can involve a large variety of processes and companies.

This information is also presented by branch in the branch descriptions. There, a short overview is given of the branch in terms of types of processes and the companies registered individually in the year 1995. These companies are obliged to publish an annual Environmental report or are selected for registration on the basis of criteria to complete a representative branch selection. Here ‘representative’ is defined as being representative from the angle of ‘environment’, expressed as a large number of pollutants. This means that the selection of companies is not necessarily covering the majority of the PM_{10} and $PM_{2.5}$ emissions in the branch, nor that these companies are necessarily representative for the PM emissions in the branch. The companies are not explicitly presented with their name if companies have a very large or a very tiny contribution to the sector emissions.

The information of these companies has been used to make a sector assessment of the ‘present’ technological situation, e.g. the type and dimensions of the process equipment installed and the de-dust technology in use. The share in sector production of the individually registered companies can be viewed as a first estimate of the representativeness of the emission and technology data; the higher the share, the more representative are the data. A higher representativeness does not necessarily mean that the data are more accurate. Sometimes, more general estimates on the basis of an accurate emission factor can be more precise. Information on this subject is not available in the framework of the present project.

Besides the individual pollutant emission register of the year 1995, a report by Haskoning on diffuse Particulate Matter emission sources has been the basis for the technological branch assessment.

The emissions of PM_{10} and $PM_{2.5}$ of the branch are reported in three categories of emission sources, viz. process emissions, diffuse emissions and combustion emissions. Diffuse emissions are defined as fugitive emissions by (un)abated building ventilation and (material handling) activities in open air. Combustion emissions are emissions from combustion processes to generate power or heat. All other emissions are due to production related industrial activities, the so-called process emissions.

These emission estimates are based upon the pollutant emission register of the year 1998.

Furthermore, the branch description includes a comparison of the present National Emission Regulation (NeR) and the EU guidelines on best available technology (BREF documents) for as far as these exist at the moment of study.

Finally, the scope of technologies to reduce sector emissions further in the future is discussed briefly.

Table D.1 Overview per branch of PM emissions and concentrations in 1998, presently installed abatement technologies (1998) and possible future measures (up to 350 €/kg) and the resulting concentrations and specific costs (technology related figures are indicative).

Source	*Present situation (1998)*					*Additional measures*			
Sector / process	PM_{10} share industry	PM_{10}	$PM_{2.5}$	Presently installed abatement technology	PM_{10} concentration	Additional abatement technology	PM_{10} concentration	Reduc-tion	Specific costs
	[%]	[ton/y]	[ton/y]		[mg/Nm^3]		[mg/Nm^3]	[%]	[€/kg PM_{10}]
Aluminium (274)	**8,9**	**1600**	**692**					**10%**	
Process	8,5	1541	686	diverse	2-30	none / fabric filter	0,5-2	10%	20-100
Diffuse	0,3	59	6	none / fabric filter		material handling		80%	5-50
Combustion									
Cement (2651)	**1,2**	**220**	**96**					**60%**	
Process	1,2	215	95	Fabric filter / ESP	35-65	Fabric filter	2	60%	20-50
Diffuse	0,0	5	1						
Combustion									
Chemicals (24)	**13,1**	**2370**	**1294**					**70%**	
Process	11,8	2129	1131	none / diverse	10-200	diverse	2-5	70%	5-250
Diffuse	0,5	85	7			material handling		80%	5-50
Combustion	0,9	156	156		30	Incineration	5	70%	
Construction (45 excl. 4531)	**5,9**	**1062**	**106**					**90%**	
Process									
Diffuse	5,9	1062	106	none	1	collection + fabric filter	2 *	90%	190
Combustion									
Food (15, 16)	**12,8**	**2300**	**386**					**90%**	
Process	10,2	1841	340	none / diverse	10-400	scrubbers / fabric filters	2-5	90%	2-150
Diffuse	2,5	459	46			mat. handling / collect +FF		80%	7-350
Combustion									
Glass (261-3)	**2,8**	**510**	**316**					**80%**	
Process	2,0	353	298	none / scrubber	30-220	Fabric filter / Wet ESP	2-5	80%	15-130
Diffuse	0,9	154	15			collection + fabric filter	2 *	70%	
Combustion	0,0	3	2	none	1				340
Iron & Steel (231, 27 excl. 274)	**16,7**	**3006**	**1803**					**80%**	
Process	7,9	1432	1289	diverse	10-100		0,1-5	80%	70-270
Diffuse	8,3	1499	448	diverse	5-10	mat. handling / collect +FF	0,1	80%	4-350
Combustion	0,4	75	66	none / ESP	10-20	ESP	2-5	70%	40
Metal working (28-35, 4531)	**3,0**	**543**	**337**					**70%**	
Process	1,6	286	286	none	1	collection + fabric filter	2 *	60%	350
Diffuse	1,4	257	51	none	1-2	collection + fabric filter	2 *	80%	350
Combustion									
Other Build M. (264-8 excl. 2651)	**6,2**	**1112**	**257**					**90%**	
Process	1,1	194	93	none	1-30	Wet ESP	2	90%	100-200
Diffuse	5,1	918	164	none	1-2	collection + fabric filter	2 *	90%	45-350
Combustion									
Paper (21)	**2,1**	**384**	**38**					**80%**	
Process									
Diffuse	2,1	384	38	none	1	collection + fabric filter	2 *	80%	150
Combustion									
Power (40001)	**3,0**	**539**	**346**					**70%**	
Process									
Diffuse	0,8	142	14			materials handling		80%	5-50
Combustion	2,2	397	332	ESP-scrubber-FF	1-10	none / fabric filter	2	70%	100
Refineries (232)	**18,8**	**3390**	**2787**					**90%**	
Process	9,5	1721	1291	none	50	ESP	5	90%	40
Diffuse									
Combustion	9,3	1669	1496	none	75-750	ESP	5	100%	25
Rubber & Plastics (25)	**0,4**	**66**	**6**					**60%**	
Process									
Diffuse	0,4	66	6	none	0,5	collection + fabric filter	2 *	60%	> 350
Combustion									
Textile (17,18)	**0,7**	**121**	**12**					**80%**	
Process									
Diffuse	0,7	121	12	none	1	collection + fabric filter	2 *	80%	280
Combustion									
Waste (9000)	**0,2**	**35**	**34**					**40%**	
Process									
Diffuse									
Combustion	0,2	35	34	ESP-scrubber-FF	3	Fabric filter	2	40%	200
Wood (20, 361)	**2,3**	**406**	**41**					**90%**	
Process									
Diffuse	2,3	406	41	none	1,5	collection + fabric filter	2 *	90%	250
Combustion									
Other industry	**2,0**	**367**	**220**						
Process									
Diffuse	2,0	367	220						
Combustion									
TOTAL INDUSTRY	**100,0**	**18000**	**8800**					**80%**	
Process	53,9	9700	5500					70%	
Diffuse	33,2	6000	1200					90%	
Combustion	12,9	2300	2100					90%	

Notes: see next page.

Notes with table D1 (previous page):
Diffuse: Fugitive emissions by (un)abated building ventilation and (material handling) activities in open air.
FF = fabric filter; ESP = Electrostatic Precipitator;
Materials handling: Measures that reduce dust emission at activities in the open air by about 50 to 80%.

* Collection + fabric filter: collection by local extraction in 10% of present building ventilation air; the dust concentration in the cleaned air is presented (which is a factor 10 higher than the overall average concentration).

1. Aluminium (sbi 274)

2742: primary and secondary aluminium, aluminium oxide (anode, electrolyses, smelting, founding, diffuse)
2743/4: zinc/copper (smelting, founding, diffuse, combustion)

1.1 Branch description

Aluminium is produced in two ways, depending on the origin of the raw material. Primary aluminium is prepared from bauxite and secondary aluminium from recycled aluminium. Only the first stage of the production process is different for the two kinds of aluminium. The final stages of the production process are the same for both primary and secondary aluminium.
The total production of aluminium in the Netherlands is about 420.000 tons per year. About 45% of this is secondary aluminium.
The other non-ferrous metal production (zinc, copper) hardly contributes to the fine dust emissions.

The production of the individually registered companies in the branch.

Aluminium		
Company name	**Annual production Sector 1998 [ton]**	**% of production by individual companies 1998**
Aldel	~ 850,000	~ 80%
Pechiney		
Aluminium Hardenberg B.V.		
Alcoa Botlek		
Aluchemie		

The representativeness of the branch data seems rather high since the share of individually registered companies is approximately 80% in terms of production.

1.2 Description of processes and sources of fine dust

Primary aluminium: Bauxite is treated with caustic soda to extract the aluminium at elevated temperatures. The aluminate solution is cooled and seeded with alumina to crystallise hydrated alumina. The crystals are washed and calcined in rotary kilns. The alumina is electrolytically reduced in a bath of molten sodium aluminium fluoride at approximately 1000°C. This electrolytic process is the main source of fine dust emission, both as process emissions and building emissions. At present time, fabric filter are used to reduce the process emissions, and washers to reduce building emissions.

Secondary aluminium: In the production of secondary aluminium, recycled aluminium parts are melted in an oven. This melting is the main source of fine dust emission in secondary aluminium production. The emissions can both be fugitive or stack emissions. Fugitive emission can be much greater than captured and abated emissions. Transfer of materials is particularly important.

1.3 Emission of fine dust and abatement techniques

The emissions of the aluminium industry contribute with almost 10% substantially to the total of industrial emissions. The vast majority of emissions consists of process emissions.

Source	**Present situation (1998)**				
Sector / process	**PM_{10} share industry**	**PM_{10}**	**$PM_{2.5}$**	**Presently installed abatement technology**	**PM concentration**
Aluminium (274)	**[%]**	**[ton/y]**	**[ton/y]**		**[mg/Nm^3]**
Process	8.5	1541	686	diverse	2-30
Diffuse	0.3	59	6	none / fabric filter	
Combustion					
Total	**8.9**	**1600**	**692**		

BREF (Non ferrous):

- Primary measures (a lot).
- Secondary measures:
  - Point sources: fabric filter, hot ESP, cyclone (pre-treatment) ⇒ 1 - 100 mg/Nm^3
  - Fugitive emissions:
  - dry dust: capture + wear resistant fabric filter or ceramic filter (1-5 mg/Nm^3)
  - sticky and abrasive dust: capture + wet ESP or Scrubber (1-5 mg/Nm^3)
  - roofline collection of fume is very energy consuming and should be a last resort.

Comparison between guidelines NeR and BREF (new installations)				
Sector	**Process**	**Reduction techniques**	**Dust concentration / emission**	
			NeR [mg/m^3]	**BREF [mg/m^3]**
Non Ferrous	Electrode baking	dry alumina + FF	10	1 - 5
	Other sources	collection + FF	10	1 - 5

1.4 Further emission reduction

On the process emissions, being the bulk of the emissions in the branch, further emission reduction with fabric filters will have a limited effect in the order of 10% since most plants already are being equipped with severe reduction measures and consequently have low dust concentrations, down to 2 mg/m^3. Material handling emissions can be reduced up to 80%, but form only a very limited part of the emissions.

Primary aluminium: Use of electrodes that are inert at the used conditions and give better energy efficiency can lead to less indirect dust emissions.
Secondary aluminium: Reuse of filter dust to increase the overall efficiency of the production unit.

2. Cement (sbi 2651)

2.1 Branch description

For the cement industry, emission data from two companies in the Netherlands are used. Together they produce 2.500.000 tons of cement (70% of the annual production) and 186 tons of fine dust (65% of the total annual fine dust emission in this branch).

2.2 Description of processes and sources of fine dust

The production of cements begins with the calcinations of calcium carbonate ($CaCO_3$) at 900°C to produce calcium oxide (CaO). This calcium oxide is reacted at high temperatures (1400-1500°C) with silica, alumina and ferrous oxide to produce clinkers. These clinkers are finally grounded and milled with gypsum to produce cement. The main sources of dust emission are the kilns, raw mills, clinker coolers and cement mills. Emission of fine dust is reduced by applying fabric filters and ESP's resulting in emission levels of 15 mg/m^3 for kilns and 10 mg/m^3 for clinker coolers.
Fugitive emission sources are storage and handling of materials and solid fuels.

The production of the individually registered companies in the branch.

Cement **Company Name**	**Annual production Sector 1998 [ton]**	**% of production by individual companies 1998**
ENCI Maastricht B.V. ENCI-Rotterdam B.V. Cementfabriek IJmuiden Bv	~ 3,500,000	100%

The representativeness of the branch data is high since all companies have been included in the individual registration.

2.3 Emission of fine dust and abatement techniques

The emissions of the cement industry contribute a little bit over 1% to the total of industrial emissions. The vast majority of emissions consists of process emissions.

Source	**Present situation (1998)**				
Sector / process	**PM$_{10}$ share industry**	**PM$_{10}$**	**PM $_{2.5}$**	**Presently installed abatement technology**	**PM concentration**
Cement (2651)	**[%]**	**[ton/y]**	**[ton/y]**		**[mg/Nm^3]**
Process	1.2	215	95	Fabric filter / ESP	35-65
Diffuse	0.0	5	1		
Combustion					
Total	**1.2**	**220**	**96**		

***<u>BREF Emission reduction</u>* (after BAT: 0.03-0.3 kg/ton clinker):**

Primary measures: no

Secondary measures:

- Point sources (kiln systems, clinker coolers and cement mills):
  - ESP or fabric filter: ⇒ 10 – 50 mg/Nm^3 (20 – 50 mg/Nm^3 on a daily basis)
- Fugitive emission reduction by Good Housekeeping:
  - open pile wind protection
  - water spray and chemical dust suppressors
  - paving, road wetting
  - mobile and stationary vacuum cleaning
  - ventilation and collection in fabric filters
  - closed storage with automatic handling system

Comparison between guidelines NeR and BREF (new installations)					
Sector	**Process**	**Reduction technique**	**Dust concentration / emission**		
			NeR *	**BREF**	
			[mg/m^3]	**[mg/m^3]**	**[kg/ton pr.]**
Cement	Cement production	FF (ESP)	10	10 - 50	
	. Kiln systems	FF (ESP)	10	10 - 50	
	. Clinker cooler	FF (ESP)	10	10 - 50	
	. Cement mills	FF (ESP)	10	10 - 50	

* If application of fabric filter is not possible, 25-50 mg is required

2.4 Further emission reduction

Additional fabric filters can lead to 60% emission reduction.

3. Chemicals (sbi 24)

Sbi 2413:	Other inorganic chemicals
Sbi 2414:	Organic and inorganic chemicals
Sbi 2415:	Fertiliser
Sbi 2416:	Plastic production
Sbi 2417:	Rubber production
Sbi 242:	Agricultural pesticides
Sbi 243:	Paint
Sbi 244:	Pharmaceuticals
Sbi 245:	Detergents and cosmetics
Sbi 246:	Other chemicals
Sbi 247:	Synthetic fibres

3.1 Branch description

A large number of companies with a large variety belong to the chemical industry. Most important companies included in the individual pollutant emission register with substantial emissions of fine dust are summarised below. These companies produce products that belong in the statistical category or sbi code 24.13 (inorganic chemicals), 24.14 (organic chemicals) and 24.15 (fertilisers). Approximately 95% of the individually registered PM_{10} emissions is being covered by the companies presented in the table.

These individually registered companies are the main source of information on applied technologies. The emissions of the total sector are estimated on the basis of the companies. This means that the emissions are not available for the (other) detailed sbi codes.

Chemicals Company Name	Sbi code
Carbon Black Nederland Bv	2413
Cabot Bv	2413
Norit Nv	2413
Hoechst Holland Nv (Vlissingen)	2413
Norit Nederland B.V.(Klazinaveen)	2413
Nedmag Industries Bv	2413
Elektroschmelzwerk Delfzijl Bv	2413
Shell Nederland Chemie Bv	2414
Nova Chemicals Netherlands Bv	2414
Dsm Limburg Bv	2414
Akzo Nobel Chemicals Bv	2414
Kemira Agro Pernis Bv	2415
Hydro Agri Rotterdam Bv	2415
Kemira Agro Rozenburg Bv	2415
Dsm Agro B.V. (IJmuiden)	2415
Zuid-Chemie Bv	2415
Hydro Agri Sluiskil Bv	2415

The representativeness of the branch data seems reasonable since the share of individually registered companies is approximately 70% in terms of PM_{10} emissions. However, scope for improvement exists since not all processes and sbi codes have been included systematically.

3.2 Description of processes and sources of fine dust

Carbon Black (inorganic, SPIN 130)
The production is based on dissection of an organic compound (oil) by partial combustion and thermal cracking (furnace process) in a horizontal reactor at temperatures of 1500 °C. Part of the tail gasses are burned in furnaces for drying of the wet carbon black granules. Emission of dust is reduced by suction and cleaning of the waste gases (fabric filters).

Silica carbide (inorganic, SPIN 141)
The production is based on chemical reduction of very pure quartz sand (SiO_2) and petroleum coke (C) in ovens at temperatures of about 2500 °C. Tail gasses are burned and energy is recovered. Dust emission during cutting of the product in the ovens and handling and storage is reduced by water spraying and good housekeeping measures.

PVC (organic, SPIN 139)
Production is based on polymerisation (chemical reaction of vinyl chloride and other reactants in an oxygen free reactor). Sources of emission of PVC-dust are the drying and handling of PVC-powder. Waste gasses are cleaned in fabric filters.

Fertiliser (fertilisers, Netherlands BAT-Fertilisers; SPIN 102, 147)
Fertilisers are produced on the basis of ores of phosphates and dolomite (and intermediate products like phosphor and sulphur acids) and basic compounds like ammonia and nitric acid. Sources of dust emissions are the handling and grinding of base materials (ores) and waste products and the drying (prilling) and handling of granules.
NeR: 10 mg/m^3 if a fabric filter can be applied, in other cases 25-50 mg/m^3
BAT: Urea plant: 100-150 g dust/ton after cleaning of granulation/cooling sections.

Salts (inorganic and organic, SPIN 166, 167)
During the production in the Solvay-process waste gases from calcining (drying) and transport are cleaned (fabric filters). Emissions of fine dust can be reduced by installation of fabric filters with higher efficiency.

3.3 Emission of fine dust and used abatement techniques

The emissions of the chemical industry contribute with more than 10% substantially to the total of industrial emissions. The vast majority of emissions consists of process emissions.

Source	**Present situation (1998)**				
Sector / process	**PM$_{10}$ share industry**	**PM$_{10}$**	**PM $_{2.5}$**	**Presently installed abatement technology**	**PM concentration**
Chemicals (24)	**[%]**	**[ton/y]**	**[ton/y]**		**[mg/Nm^3]**
Process	11.8	2129	1131	none / diverse	10-200
Diffuse	0.5	85	7		
Combustion	0.9	156	156		30
Total	**13.1**	**2370**	**1294**		

The following table illustrates that the fertiliser industry is responsible for a large portion of the emissions, followed by the inorganic chemical production (including silica carbide, active carbon and carbon black).

Chemical subsector	**PM$_{10}$ emission [ton/y]**
fertiliser	745
other organic	190
inorganic	1158
other chemicals	277
Total	**2370**

3.4 Further emission reduction

A large diversity of reduction measures can reach up to 70% emission reduction.

4. Construction (sbi 45 excl. 4531)

4.1 Branch description

This branch deals with the erection of new buildings and the dismantling of old buildings. Sbi 4531 involves welding in construction and is included in Metal working.

4.2 Description of processes and sources of fine dust

Activities that generate dust are the preparation of the site (handling of soil), the dismantling of old buildings and activities related to reuse of old building materials (breaking of used bricks). The dust generating activities take place in the open air.

The emission estimate is not based upon individual registered companies but on a collective estimate. The total sector concerns over 25,000 companies. The representativeness of the emission estimation is not known.

4.3 Emission of fine dust and abatement techniques

The emissions of the construction sector contribute more than 5% to the total of industrial emissions. The vast majority of emissions consists of diffuse emissions (material handling).

Source	**Present situation (1998)**				
Sector / process	**PM_{10} share industry**	**PM_{10}**	**$PM_{2.5}$**	**Presently installed abatement technology**	**PM concentration**
Construction (45 excl. 4531)	**[%]**	**[ton/y]**	**[ton/y]**		**[mg/Nm^3]**
Process					
Diffuse	5.9	1062	106	none	1
Combustion					
Total	**5.9**	**1062**	**106**		

Emission reduction can be accomplished by wetting the surfaces or working in (temporary) closed compartments with extracting and cleaning of dust-laden air.

4.4 Further emission reduction

Measures to reduce dust emission concern the collection of dust (herewith increasing the concentration of the waste gas flow) and dedusting it with fabric filters. This relatively expensive measure can reach up to 90% emission reduction.

5. Food (sbi 15, 16)

5.1 Branch description

There are a lot of companies belonging to the food industry (foods for humans and animals).
Most important food categories with emissions of fine dust are summarised below, with the specific product produces and the relevant dust sources between brackets.

154: Oils/fats
155: Dairy (spray dryers)
156: Meal: Flour (dryers); Starch (dryers: potato/wheat)
157: Cattle food (dryer: pulp/grass)
158: Sugar (dryer: sugar/pulp), Cacao (roasting/crushing), Coffee (roasting/crushing), Bakery
159: Beverages
160: Tobacco.

The production of the individually registered companies in the branch.

Food ***Company Name***	**Annual production Sector [ton]**	**% of production by individual companies**
Oils and fats		
Speelman'S Oliefabrieken B.V.		
A.D.M. Europoort B.V.	~ 4,500,000	~ 70 %
Cereol Benelux B.V.	(1995)	
Cargill B.V. (Coenhavenweg)		
Starch		
Amylum Nederland B.V.	~ 1,200,000	~ 50 %
Cargill Bv.	(1991)	
Cerestar Benelux Bv		
Latenstein Zetmeel Bv		
Avebe Loc. Gasselternijveen		
Avebe Ba Loc. D.W.M. Veendam		
Avebe Ter Apelkanaal		
Avebe Ba Lokatie Foxhol		
Sugar		
Suiker Unie	~ 1,000,000	~ 70 %
CSM Suiker Bv Fab."Wittouck"	(1988)	
Coop.Vereniging Suikerunie U.A		
Sensus Operations Cv		
Suiker Unie Vest.Groningen		
CSM Suiker Bv "Vierverlaten"		
Cattle food		
Cc Landbouwbelang Maasbracht		
Cc Landbouwbelang Ua (Wanssum)		
Kon. Mengv. Ind. Meulemans Bv		
Cehave Nv		
Nutrifeed		
Schouten Industries Bv		
Coop. Grasdrogerij Ruinerwold	*	*
Coop.Grasdrogerij Opeinde E.O.		
Coop.Groenv.Drog. Gaasterland		
Coop Grasdrogerij Pasveer		
Coop. Groenv.Drog. Oosterwolde		
Sloten Jongveevoeders		
B.V."Oldambt"		
Groenvoerdrogerij Flevoland Bv		

* Total sector unknown

The representativeness of the branch data seems reasonable since the share of individually registered companies is varying from 50% to 70% in terms of production for a number of important subsectors. However, scope for improvement exists since not all subsectors (sbi codes) and processes have been included systematically.

5.2 Description of processes and sources of fine dust

Oils and fats (SPIN 175, BREF)
Dust emissions in this branch are almost completely caused by processing of seeds and (soy)beans (4.400.000 ton/year) to vegetable oils. Processing consists of cleaning (dust emission), husk/hull cracking (dust emission), conditioning, pressing, crushing (dust emission) and extraction of oil with hexane. Waste products (soy scrap) is dried and transferred (dust emission).
NeR: 10 mg/m^3 if a fabric filter can be applied, in other cases 25-50 mg/m^3

Dairy (SPIN 157)
In the dairy industry about 480 companies process raw milk (11.400.000 ton/year) to produce milk and milk products. In ERI 6 companies are mentioned that produce milk powder in spray dryers. To separate the powder from the air product cyclones are installed behind the dryers. These cyclones are the most important sources of dust emission. Most of the dryers are equipped with end of pipe emission reduction techniques (fabric filters and/or scrubbers). Other dust sources are combustion installations for heating purposes.
NeR: 10 mg/m^3 if a fabric filter can be applied, in other cases 25-50 mg/m^3

Starch (SPIN 165, BREF)
Most important base materials for production of starch are potatoes, wheat and wheat flour. One company (Avebe) with several production locations produces starch (465.000 ton/year) from potatoes. Processing consists of: cleaning/washing potatoes, milling, extraction/refining of starch, drying and storage ((starch)dust emission) in silos.
About 5 companies (Meneba, Amylum, Cargill, Cerestar, Latenstein) are in ERI that produce starch from wheat and wheat flour (branch capacity: 3.000.000 ton/year). Handling, separation and drying of products (starch and waste) are sources of dust emission
NeR: dust concentration of starch dryer: 50 – 100 mg/m^3.

Cattle food (BREF)
Most emissions of dust take place at direct dryers for grass and pulp together with combustion particles. Most dryers are equipped with cyclones to separate course particles from the emitted waste gasses. At all of the other processes (reception of food basic materials, weighing, grinding, blending/pressing, cooling and storage/packaging) emissions of dust are relevant. If these emissions are not reduced by locally extraction and cleaning they are emitted to the atmosphere by ventilation of the buildings.

Sugar (SPIN 110, BREF)

There are two main producers (Suiker Unie and CSM) of sugar (1.000.000 ton/year) from sugar beets. The production process consists of 6 primary processes (cleaning of beets, winning of juice, juice purification, juice concentration/crystallization, separation of crystals, drying/cooling/storage of sugar) and some secondary processes (direct drying of beet pulp with combustion gasses, calcination, combustion for heating purposes).
The main sources of dust emission are the sugar dryers and the dryers for beet pulp with emission of combustion and pulp particles.
NeR: pulp dryer:

- with multi-cyclones: < 75 mg/m^3.
- new installations with steam drying: negligible.

Cacao (SPIN 118)

In this branch raw imported cacao beans (300.000 ton/year) are processed to semi-finished products like cacao mass, cacao butter and cacao powder. Cacao beans are supplied in bags and are cleaned before processing (dust emission). The beans are broken and the shells are separated from the nibs in winnowers (dust emission). After preparation the nibs are roasted to temperatures of 100 tot 140 °C by direct or indirect heating with waste gases from natural gas burners (aerosol emissions are extracted by suction). After crushing (dust emission) and pressing to separate cacao cake from cacao butter the cake is cooled and milled to cacao powder, transported and sacked (dust emission). Air from locations with emission of dry dusts is extracted and cleaned in fabric filters. Waste gases from roasting and milling cacao cake contain fatty aerosols that cannot be cleaned by fabric filters.
NeR: 10 – 50 mg/m^3

Tobacco

Dust emissions during the production of tobacco occur at several stages. All emissions are released in the production building and emitted to the atmosphere by ventilation.

Coffee (SPIN 121, BREF)

In this branch raw imported coffee beans (137.000 ton/year) are supplied in bags and are cleaned before processing (dust emission). The beans are roasted in roasters by hot air with temperatures of 300 to 500 °C (dust emission). After cooling and grinding (dust emission) the coffee is dried (dust emission), transported and packed under vacuum.
Roaster gasses are cleaned in cyclones (separation of skins) and partly recycled. Crushing rooms are vented and extracted air is cleaned by cyclones and/or fabric filters.
NeR: 10 – 50 mg/m^3.

Bakery (BREF)
Dust emissions during the production of bread and pastry occur at several stages related to cleaning/milling of grain and handling/mixing of flour. All emissions are released in the production building and emitted to the atmosphere by ventilation.

5.3 Emission of fine dust and abatement techniques

The emissions of the food industry contribute with more than 10% substantially to the total of industrial emissions. The vast majority of emissions consists of process emissions.

Source	Present situation (1998)				
Sector / process	PM_{10} share industry	PM_{10}	$PM_{2.5}$	Presently installed abatement technology	PM concentration
Food (15, 16)	[%]	[ton/y]	[ton/y]		[mg/Nm^3]
Process	11.7	2116	340	none / diverse	10-400
Diffuse	1.0	184	46		
Combustion					
Total	**12.8**	**2300**	**386**		

The next table presents the contributions of the different subsectors, illustrating the importance of starch and cattle food.

Subsector Food	PM_{10} emission [ton/y]
Oil and fats	185
Dairy	198
Flour	39
Starch	728
Cattle food	1004
Cacao	87
Sugar	32
Bakery	12
Other	15
Total	**2300**

5.4 Further emission reduction

Measures to reduce dust emission concern the collection of dust (herewith increasing the concentration of the waste gas flow) and dedusting it with fabric filters. This relatively expensive measure can reach up to 80% emission reduction.

6. Glass (sbi 261-3)

Sbi 261: Glass production
Sbi 262-3: Fine ceramics

6.1 Branch description

To investigate the possibilities for fine dust emission reduction, emission data from the Individual Emission Registration (ERI) of 1998 for 6 companies/establishments are used:

- Glaverbel (former Maasglas BV) (Float glass)
- Glasspack (former Verenigde glasfabrieken) (3 establishments, Container glass)
- Isover B.V. (Glass wool)
- PPG Industries Fiber Glass B.V. (Fiber Glass)

The total annual production of these companies is close to 90% of the total production of glass (980,000 ton).

Fine ceramics (Sbi 262-3): There are about 20 companies producing fine ceramics (pottery, wall tiles, sanitary). Almost 75% of fine ceramics is produced by two companies.

It can be concluded that the representativeness of the branch data seems satisfactory.

6.2 Description of processes and sources of fine dust

General
In the production of glass, a mixture of sand, intermediate/modifying materials (e.g. soda ash, limestone to avoid bubbles, feldspar) and colouring/decolouring agents (e.g. iron chromite, iron oxide) is molten at high temperature (1400-1550°C) to form a molten glass. The main sources of fine dust emission are the melter ovens. Additional to the conventional combustion products, the main emission products are Sodium sulphate (Na_2SO_4) and borates.

Float glass production
The basic principle of the float process is to pour the molten glass onto a bath of molten tin, and to form a ribbon with the upper and lower surfaces becoming parallel under the influence of gravity and surface tension.

Container glass production

The molten glass flows from the furnace along a fore hearth to a gathering bowl (spout) at the end. These glass streams are cut into accurate lengths by a shear mechanism to form primitive, sausage shaped, glass "gobs”. The initial forming of the blank may be made either by pressing with a plunger, or by blowing with compressed air, according to the type of container. The final moulding operation is always by blowing to obtain the finished hollow shape.

Glass fibre production

The molten glass flows from the front end of the furnace through a series of refractory lined, gas-heated canals to the fore hearths. Bushings are complex box-like structures with a perforated metal plate (bushing plate) at the base, with several hundred calibrated holes (bushing tips). The glass flowing through the bushing tips is drawn out and attenuated by the action of a high speed winding device to form continuous filaments.

Glass wool production

A stream of molten glass flows from the furnace along a heated refractory lined fore hearth and pours through a number (usually one to ten) of single orifice bushings into specially designed rotary centrifugal spinners. Primary fiberising is by centrifugal action of the rotating spinner with further attenuation by hot flame gases from a circular burner.

Fine ceramics

The manufacture of pottery, wall tiles, sanitary and related products involves the preparation of the raw materials, followed by the forming, cutting or shaping, and firing of the final product. In contrary with coarse ceramics the fine ceramics are almost always glazed before firing. The raw materials (clay, water and additives) are mixed (dust emission) and the products are formed into the shape of the final product. The products are then heated. Three stages of heating are involved: the initial drying period with high volumes of hot air of 30 – 110 °C, the oxidation preheating period and the finishing period in a kiln at final temperatures of 900 – 1250 °C (dust emission).

6.3 Emission sources and reduction

Glass

The main sources of fine dust emissions from glass production are the melting ovens. The oven producing glass wool is equipped with a wet scrubber or ESP, resulting in relative low PM_{10} emission levels (ca 30 mg/m^3) the other ovens use no reduction techniques and have higher PM_{10} emission levels (100-250 mg/m^3).

Dust sources:

- handling fine materials;

- melting: condensation of volatiles, entrainment of fine material, combustion of fuel;
- forming: mineral wool or ceramic fibre;
- downstream processing: cutting/polishing;
- packaging.

Part of the fine dust is released to the atmosphere as diffuse emissions.

The emissions of glass industry contribute less than 3% to the total of industrial emissions. The majority of emissions consists of process emissions and to a lesser extent diffuse emissions.

Source	**Present situation (1998)**				
Sector / process	**PM_{10} share industry**	**PM_{10}**	**$PM_{2.5}$**	**Presently installed abatement technology**	**PM concentration**
Glass (261-3)	**[%]**	**[ton/y]**	**[ton/y]**		**[mg/Nm^3]**
Process	2.0	353	298	none / scrubber / ESP / fabric filter	30-220
Diffuse	0.9	154	15		
Combustion	0.0	3	2	none	1
Total	**2.8**	**510**	**316**		

Emission reduction (BAT):

Primary measures (not as effective as secondary):

- changes in raw materials
- furnace/firing modification

Secondary measures (BAT) for Container/flat/fibre/wool glass:

⇒ 0.1 – 0.15 kg/ton glass

- ESP (2/3 stage) : 95-99% for 0,1-10µm Þ < 20 mg/Nm^3
- Fabric filters: 95-99% for 0,1-10µm Þ < 10 mg/Nm^3

Comparison between guidelines NeR and BREF (new installations)					
Sector	**Process**	**Reduction technique**	**Dust concentration / emission**		
			NeR	**BREF**	
			[mg/m^3]	**[mg/m^3]**	**[kg/ton pr.]**
Glass	Melting	FF or ESP	10 / 25	< 10 - 20	< 0.1
	. Container/Flat glass	FF or ESP	10 / 25	5 - 30	< 0.1
	. Fibre glass	FF or ESP	10 / 25	5 - 30	< 0.14
	. Glass wool	FF or ESP	10 / 25	5 - 30	< 0.1

Fine ceramics

Most flue gas cleaning systems currently in operation are dry absorption based processes: packed bed filters and cloth filters.

In packed bed filters the flue gas passes through a filter bed of granular limestone for absorption of gaseous pollutants and deposition of dust.
At cloth filter systems lime or hydrated lime is injected into the gas stream to absorb the gaseous pollutants followed by a fabric filter to separate polluted lime and dust from the waste gasses.
Both systems are able to reach dust concentrations in the treated waste gasses of < 50 mg/m^3.
Other dust emissions are reduced by local extraction and venting systems. The extracted air is mostly passed through fabric filters before discharge.
NeR: 10 – 25 mg/m^3.

6.4 Further emission reduction

Primary control techniques are based mainly on raw material changes and furnace/firing modifications. In most applications primary techniques cannot yet achieve emission levels comparable with FF and ESP's.

Secondary control techniques are focused on better fabric filters (or electrofilters) to reduce emission levels of melter ovens to 5 (or 30) mg/Nm^3. In this way, emission of fine dust can be reduced by 85% to less than 0.15 kg dust per ton glass(fibre).

Measures to reduce diffuse dust emission concern the collection of dust (herewith increasing the concentration of the waste gas flow) and dedusting it with fabric filters. This relatively expensive measure can reach up to 70% emission reduction.

7. Iron & steel (sbi 231, 27 excl. 274)

Sbi 231: Coke oven
Sbi 271: Iron & steel
Sbi 272: Pipe production
Sbi 273: Rolling mill
Sbi 275: Iron/steel foundries (casting)

7.1 Branch description

The iron and steel industry is a highly material and energy intensive industry. More than half of the total amount of starting materials is converted to waste gases and by-products.
Steel is produced from pig iron, scrap and additives. The Basic Oxygen Furnace (BOF) is world-wide the most predominant process to produce primary steel. Sinter plants and pelletisation plants are both used to prepare starting material for primary iron and steel making. In the Netherlands, steel making is only performed by Corus and Nedstaal (primary steel production).
Iron/steel foundries produce steel castings (carbon steel, low-alloy steel or high-alloy steel) from molten steel that are used in machinery, transportation, and other industries requiring parts that are strong and reliable (secondary steel production). The other Dutch companies fall in this category.

Coke ovens are included in the iron and steel sector, since the coke production is closely related to the steel production.

The production of the individually registered companies in the branch.

Iron & Steel		
Company Name	**Annual production Sector 1998 [ton]**	**% of production by individual companies 1998**
Corus Nedstaal B.V. De Globe Bv Gieterij Doesburg Bv Ned.IJzergiet.Vulcanus Bv (Dt) Lovink Terborg Bv Rademakers Gieterij Bv	~ 27,000,000	100%

The representativeness of the branch data is high since all companies have been included in the individual registration.

7.2 Description of processes and sources of fine dust

Iron and Steel: Iron and steel plants can be separated in several processes, which will all be described briefly here. Sinter plants and pelletisation plants are both used to prepare starting material for primary iron and steel making. Local conditions such as the availability and type of raw materials govern the choice for one of these techniques.

Sinter

In sinter plants, raw materials are blended and burned to produce sinter. Fine dust emissions are a result of burning the raw materials.

Pelletisation

In pelletisation plants, raw material is grinded to small crystallized balls of iron size are produced by as starting material for primary iron and steel making. The main emission source of pelletisation plants is grinding of the raw material.

Coke oven

In coke oven plants coal is pyrolised by heating the coal to 1000-1100°C in an oxidation free atmosphere. The products of coke oven plants are gases, liquids char and coke. The main sources of fine dust from coke oven plants are coal handling, coke handling and coke oven gas.

Blast furnace

Blast furnaces are used to produce pig iron. In a closed system, iron bearing materials (iron ore, sinter and/or pellets), additives and reducing agents (coke) are heated to continuously reduce iron to form metal iron. Main sources of fine dust are the cast house, and BF-gas released in the process.

Basic oxygen steel

Basic oxygen steel making uses oxygen instead of air for the production of steel. In basic oxygen steel making, undesirable impurities in the metal feedstock are burnt to the corresponding oxides. Undesirable impurities are among other things, carbon, silicon, manganese, phosphorous and sulphur. Main source of fine dust is BOF gas.

Electric steel making

In electric steel making, iron-containing materials are melted in an electric arc furnace. These iron-containing materials can be ferrous scrap, cut-offs from steel producers and recycled iron. Fine dust emissions arise from the furnace, and from building evacuation.

Iron/steel foundries

The major processing operations of a typical steel foundry are the raw materials handling (receiving, unloading, storing and conveying), the metal melting process (scrap preparation, furnace charging, closed melting, back charging, oxygen lancing and tapping), mould and core production, and casting and finishing. At almost all of the mentioned activities there are emissions of fine particulates.

7.3 Emission of fine dust and abatement techniques

The emissions of the iron and steel sector contribute with more than 15% substantially to the total of industrial emissions. The vast majority of emissions consists of process emissions and diffuse emissions (building ventilation and material handling).

Source	**Present situation (1998)**				
Sector / process	**PM_{10} share industry**	**PM_{10}**	**$PM_{2.5}$**	**Presently installed abatement technology**	**PM concentration**
Iron & Steel (231, 27 excl. 274)	**[%]**	**[ton/y]**	**[ton/y]**		**[mg/Nm^3]**
Process	7.9	1432	1289	diverse	10-100
Diffuse	8.3	1499	448	diverse	5-10
Combustion	0.4	75	66	none / ESP	10-20
Total	**16.7**	**3006**	**1803**		

Comparison between guidelines NeR and BREF (new installations)					
Sector	**Process**	**Reduction technique**	**Dust concentration / emission**		
			NeR	**BREF**	
			[mg/m^3]	**[mg/m^3]**	**[kg/ton pr.]**
Iron and Steel	Sinter strand	Advanced ESP	100	< 50	
	. idem	ESP + HES*	100	< 50	
	. idem	ESP + (lime) + FF	10	10 - 20	
	Pelletisation				< 0.1
	. Induration strand	Wet scrubber or FF	10	< 10	
	. Dry grinding mills	ESP	10	< 50	
	. Drying	FF (wet scrubber)	10	< 20	
	Coke oven plant				
	. Charging	collection + FF	10	< 30	< 0.005
	. Pushing	Collect.+ FF+ quenching	10	< 30	< 0.005
	. Quenching	wet quenching	<0.06 kg/t		< 0.05
	Blast furnace				
	. Furnace gases	wet scrubber or wet ESP	25	< 10	
	. Cast house	collection + (FF or ESP)	effic. >99%	1 - 15	
	Basic Oxygen Steel				
	. Hot metal pre-treatment	collection + FF	10	5 - 15	
	. idem	collection + ESP	10	20 - 30	
	. Fugitive		< 5 g/ton		5 - 15 g/ton
	Electric Steel making	collection (>98%) + FF	10	5 -15	

* It concerns a high pressure wet scrubber

Sinter Plant (BREF - sinter strand)

- Primary measures: Waste gas minimisation by re-circulation
- Secondary measures at point sources:
- Advanced ESP: ⇒ 50 mg/Nm^3:
- ESP + lime/fabric filter: ⇒ 10-20 mg/Nm^3;
- Pre-dedusting (ESP or cycl.) + high pressure wet scrubbing: ⇒ 50 mg/Nm^3

Pelletisation plant (BREF)

- Secondary measures at point sources:
- Grinding mills: ESP ⇒ < 50 mg/Nm^3
- Drying and induration zone: Scrubber (η>95%) ⇒ < 20 mg/Nm^3

Coke oven plant (BREF)

- Secondary measures at battery operation:
  - charging: collection + fabric filter ⇒ < 5g/ton coke
  - pushing: collection + fabric filter ⇒ < 5g/ton coke (< 30 mg/ Nm^3)
  - quenching: wet scrubber (η=90%) ⇒ < 50g/ton coke
- Fugitive: Good housekeeping (e.g. sealing)

Blast furnace (BREF)

- Primary measures: gas recovery, direct injection of reduction agents, tar-free runner linings, covering runners with movable lids, fume suppression with inert gas
- Secondary measures:
- Blast furnace gases: scrubber or wet ESP or other ⇒ <10 mg/Nm^3
- Cast house (tap-holes, runners, skimmers, etc.):
  - collection +fabric or ESP ⇒ 1-15 mg/Nm^3
  - fugitive emission (others) ⇒ 5-15g/ton pig iron

Basic Oxygen Steel making and Casting (BREF)

- Primary measures:
- Basis Oxygen Furnace (BOF)-gas recovery: suppressed combustion
  - hot metal handling: fume suppression with inert gas
- Secondary measures: evacuation + fabric or ESP ⇒ 10-15 or 20-30 mg/Nm^3
- BOF gas recovery: after suppressed combustion
  - pig iron pre-treatment, charging and tapping, hot metal handling, ventilation system

Electric Steel making and casting (BREF)

- Primary measures: Electric Arc Furnace (EAF) dust recycling
- Secondary measures: Dust collection (>98%) + fabric filter: ⇒ 5-15 mg/Nm^3
- direct EAF gas extraction and hood systems or
- dog-house and hood system or
- total building evacuation

Metals working
Capture and collection systems during welding may be used to catch the fumes at the source and to remove the fumes with a collector (high efficiency filters, ESP, Scrubbers and Active carbon). Not captured fumes will be emitted to the atmosphere by building ventilation.

Iron/steel foundries
Controls for emissions during melting and refining operations focus on venting the furnace gasses and fumes directly to an emission collection and control system (bag filters, cyclones and venturi scrubbers). Other fugitive emissions are emitted to the atmosphere by building ventilation.

7.4 Further emission reduction

For sinter plants, emerging techniques are mainly concerned in reducing the amount of halogenated organic compounds released from the process.
Emerging techniques for pelletisation plants are focused on reducing emission of NO_x and SO_2.
Several new processes are developed to improve the performance of coke oven plants. These new processes will use less fuel and will reduce the total emissions from the coke oven plant.
Blast furnaces use coke as the main fuel, which results in high emission levels. New techniques are being developed to use coal as fuel.
In basic oxygen steel making, new developments are not focused on reducing dust emission, but on zinc recovery and desulphurisation.
For electric arc furnaces, new furnace types are being developed which reduce energy consumption and dust emission.

Measures to reduce diffuse dust emission concern the collection of dust (herewith increasing the concentration of the waste gas flow) and dedusting it with fabric filters. This relatively expensive measure can reach up to 90% emission reduction.

8. Metal working (sbi 28-35, 4531)

Sbi 28: metal products
Sbi 29-35: metal/electro
Sbi 4531: welding in construction

8.1 Branch description

The metal working industry can be divided in different industries that manufacture metal products like flats, bars, wires, pipes, formed parts, transmission elements and machinery/appliances.

The estimation of emissions is based upon a collective emission estimate per process, not on individually registered companies. The representativeness is not known.

8.2 Description of processes and sources of fine dust

In the metal working industry the processes with dust emissions are foundries, hot and cold forming, metal removal operations, connecting techniques (welding) and surface treatment [SPIN 101, 125, 129, 134, 159, 176].

Forming
The hot and cold forming processing comprises different manufacturing methods, such as hot rolling, cold rolling and drawing of steel. In hot rolling the size, shape and metallurgical properties of steel are changed by repeatedly compressing the hot metal between rollers. In cold rolling the properties of the hot rolled strip products are changed without heating. Dust emissions arise from product handling and hot rolling.

Welding
Welding is the process by which 2 metal parts are joined by melting the parts at the points of contact and simultaneously forming a connection with molten metal from these same parts or from a consumable electrode. In welding, the most frequently used methods for generating heat employ either an electric arc or a gas-oxygen flame. Other operations include brazing, soldering, thermal cutting, and gauging operations. During welding operations emission aerosols occur (particulate matter and particulate-phase hazardous air pollutants). Electric arc welding has the greatest emission potential (particulate matter and particulate-phase hazardous air pollutants). All particulate emissions are PM_{10} and contain hazardous metals (Mg, Ni, Cr, Co, and Pb).

Surface treatment

Surface treatment processes that generate dust emissions are (sand) blasting and dry sanding. The air extracted from the blasting cabin or compartment is the source of dust emission.

8.3 Emission of fine dust and abatement techniques

The emissions of the metal working contribute with 3% to the total of industrial emissions. The vast majority of emissions consists of both process emissions and diffuse emissions (building ventilation).

Source	Present situation (1998)				
Sector / process	PM_{10} share industry	PM_{10}	$PM_{2.5}$	Presently installed abatement technology	PM concentration
Metal working (28-35, 4531)	**[%]**	**[ton/y]**	**[ton/y]**		**[mg/Nm^3]**
Process	1.6	286	286	none	1
Diffuse	1.4	257	51	none	1-2
Combustion					
Total	**3.0**	**543**	**337**		

Welding

Capture and collection systems may be used to catch the fumes at the source and to remove the fumes with a collector (high efficiency filters, ESP, Scrubbers and Active carbon). Not captured fumes will be emitted to the atmosphere by building ventilation.

Surface treatment

Generated dust particles can be captures locally by extracting air and dedusting in fabric filters. All blasting cabins and compartments are equipped with dedusting installations.

Comparison between guidelines NeR and BREF (new installations)					
Sector	Process	Reduction technique	Dust concentration / emission		
			NeR	BREF	
			[mg/m^3]	[mg/m^3]	[kg/ton pr.]
Ferrous Metals	Hot rolling				
	. Dry dust	enclosure + FF	10	< 5 - 20	
	. Wet fumes	enclosure + ESP	25	< 10 - 50	
	Cold rolling				
	. Decoiling / levelling/ welding	collection + FF	10	< 5 - 20	

BREF

Cold rolling:

- Primary measures at pickling: corrosion prevention, mechanical descaling, electrolytic pre-pickling, spray or turbulence pickling, enclosed pickling tanks.
- Fugitive emission: Mechanical descaling operations: 10-20 g/ton en < 1 – 25 mg/Nm^3.
- Hot rolling:
- Unabated fugitive emission concentrations: 5 – 100 mg/Nm^3
- Fugitive: reheating and heat treatment furnaces (no measures): < 5 – 20 mg/Nm^3

8.4 Further emission reduction

Measures to reduce dust emission concern the collection of dust (herewith increasing the concentration of the waste gas flow) and dedusting it with fabric filters. This relatively expensive measure can reach up to 60-80% emission reduction.

9. Other building materials (sbi 264-8 excl. 2651)

sbi 264 (SPIN 112, 119; UK): Coarse ceramics (clinker/brick)
sbi 2652-3 (BREF): Lime (chalk, gypsum, basics)
sbi 266: Products of cement, lime etc.
sbi 267/8: Not-metal minerals: Mineral wool (SPIN 114), natural stone

9.1 Branch description

This branch consists of all building materials except the materials in the sector glass (sbi 261-3) and cement (2651-2).

Lime
Lime is used in a wide range of products, for example as a fluxing agent in steel refining, as a binder in building and construction, in water treatment to precipitate impurities, for neutralisation of acidic components in effluent and flue gases.

Coarse ceramics
The three most import types of companies in the coarse ceramics branch are: brick production, roofing tile production and floor tile production.

Mineral wool
One company (Rockwool) produces mineral wool mainly for (heat) insulation purposes.

The estimation of emissions is based upon an almost 100% coverage of individually registered companies. The representativeness is regarded to be high. The number of companies is too high to present them here.

9.2 Description of processes and sources of fine dust

Lime
The lime making process consists of the burning in a kiln (calcining) of calcium and/or magnesium carbonates to liberate carbon dioxide and to obtain the derived oxide. Kilns are fired with solid, liquid or gaseous fuels (dust emission in flue gases). The calcium oxide product from the kiln is generally crushed, milled and/or screened (dust emission) before being conveyed to silo storage. From the silo some of the calcium oxide (quicklime) can be transferred to a hydrating plant where it is reacted with water to produce calcium hydroxide (slaked lime).

Coarse ceramics

The manufacture of bricks and related products involves the preparation of the raw materials, followed by the forming, cutting or shaping, and firing of the final product. In contrary with coarse ceramics the fine ceramics are almost always glazed before firing. The raw materials (clay, water and additives) are mixed (dust emission) and the products are formed into the shape of the final product. The products are then heated. Three stages of heating are involved: the initial drying period with high volumes of hot air of 30 – 110 °C, the oxidation preheating period and the finishing period in a kiln at final temperatures of 900 – 1250 °C (dust emission).

Mineral wool

The manufacture of mineral wool involves the processes: melting (dust emission), spinning (dust emission), hardening, cooling and cutting (dust emission). Raw material used is volcanic stone. In an oven a mixture of stone, blast-furnace slag, coke, natural gas and air is smelted (1500 °C).

9.3 Emission of fine dust and abatement techniques

The emissions of the other building materials contribute with more than 5% substantially to the total of industrial emissions. The vast majority of emissions consists of diffuse emissions from building ventilation.

Source	**Present situation (1998)**				
Sector / process	**PM_{10} share industry**	**PM_{10}**	**$PM_{2.5}$**	**Presently installed abatement technology**	**PM concentration**
Other Build M. (264-8 excl. 2651)	**[%]**	**[ton/y]**	**[ton/y]**		**[mg/Nm^3]**
Process	1.1	194	93	none	1-30
Diffuse	5.1	918	164	none	1-2
Combustion					
Total	**6.2**	**1112**	**257**		

Lime

BREF Emission reduction (BAT)

Primary measures: no

Point sources: fabric filter or ESP or wet scrubber: ⇒ <5 - 50 mg/Nm^3 ⇒ 0.1 - 0.3 kg/tonne

- Calcining of limestone (kilns): bag filter/ESP: 0.1 - 0.2 kg/tonne;
- Lime hydrating: bag filter/wet scrubber: 0.02 kg/tonne;
- Lime grinding/milling: bag filter: 0.03 kg/tonne.
- Subsidiary operations (crushing, screening, conveying, slaking, storage and discharge):

- Containment + extracting air + bag filters

Fugitive: Good housekeeping (see Cement)

Comparison between guidelines NeR and BREF (new installations)					
Sector	**Process**	**Reduction technique**	**Dust concentration / emission**		
			NeR [mg/m^3]	**BREF [mg/m^3]**	**[kg/ton pr.]**
Lime	Calcining of Lime	FF / ESP	10 / 25	< 5 - 20	0.1 – 0.2
	Hydrating	FF / wet	10 / 25	< 5 - 20	0.02
	Grinding and milling	FF	10		0.03

Ceramic filters are not currently used on lime kilns. They are able to remove dust very efficiently at high temperatures and it is possible that, with kilns such as rotary kilns producing dead-burned dolomite, de-dusting high temperature gases might enable certain heat recovery systems to become viable.

Coarse ceramics

Most flue gas cleaning systems currently in operation within the brick industry are dry absorption based processes: packed bed filters and cloth filters.

In packed bed filters the flue gas passes through a filter bed of granular limestone for absorption of gaseous pollutants and deposition of dust.

At cloth filter systems lime or hydrated lime is injected into the gas stream to absorb the gaseous pollutants followed by a fabric filter to separate polluted lime and dust from the waste gasses.

Both systems are able to reach dust concentrations in the treated waste gasses of < 50 mg/m^3.

Other dust emissions are reduced by local extraction and venting systems. The extracted air is mostly passed through fabric filters before discharge.

NeR: 10 – 25 mg/m^3.

Mineral wool

Flue gases from the oven are incinerated and after subsequently de-dusted in flue gas filters. Waste air from the spinning room contains dust and other pollutants and is cleaned in a filter made of mineral wool blankets. Dust emission from cutting/sawing the blankets is reduced by local extraction and venting systems. The extracted air is passed through fabric filters before discharge.

NeR: 10 mg/m^3 if a fabric filter can be applied, in other cases 25-50 mg/m^3

9.4 Further emission reduction

Wet ESP can reduce process emissions up to 90%.

Measures to reduce diffuse dust emission concern the collection of dust (herewith increasing the concentration of the waste gas flow) and dedusting it with fabric filters. This relatively expensive measure can reach up to 90% emission reduction.

10. Paper (sbi 21)

10.1 Branch description

For the paper industry in the Netherlands, only emission data from building emissions are available, based upon a collective emission estimation. The representativeness is not known. The total sector concerns over 500 companies. The total fine dust emission from the paper industry caused by building emissions is about 384 ton/year.

10.2 Description of processes and sources of fine dust

In paper production fibres are dissolved in water in low concentrations (less than 1%) and passed through a sieve. The paper pulp remains on the sieve, producing thin sheets of paper, which are dried and cut to size. Only very low concentrations of dust arise form the production process. Another source of fine dust emission is the power generator where fuels are burnt to produce electricity or steam.

10.3 Emission sources and reduction

The emissions of the paper industry contribute 2% to the total of industrial emissions. The main emission sources in paper industry are building emissions. Because of the very low concentrations of fine dust, no reduction techniques are installed to reduce PM_{10} emission for paper production.

Source	**Present situation (1998)**				
Sector / process	**PM_{10} share industry**	**PM_{10}**	**$PM_{2.5}$**	**Presently installed abatement technology**	**PM concentration**
Paper (21)	**[%]**	**[ton/y]**	**[ton/y]**		**[mg/Nm^3]**
Process					
Diffuse	2.1	384	38	none	1
Combustion					
Total	**2.1**	**384**	**38**		

10.4 Further emission reduction

Due to the very low PM_{10} concentrations in waste gas streams from paper industry, measures to reduce dust emission concern the collection of dust (herewith increasing the concentration of the waste gas flow) and dedusting it with fabric filters. This relatively expensive measure can reach up to 90% emission reduction.

11. Power (sbi 40)

11.1 Branch description

Power stations generate electricity by combustion of fossil fuels (natural gas, oil or coal). Only the combustion of heavy oil (3 plants) and coal (5 plants) results in flue gasses with high concentrations of dust. All these power stations are individually registered. The representativeness is therefore regarded as high.
Coal fired power stations used about 6000 kton of coal in 1998 and are responsible for almost all emissions of dust in this branch.

The production of the individually registered companies in the branch.

Power		
Company Name	**Annual production Sector 1998 [kWh]**	**% of production by individual companies 1998**
Nv.EPZ Lok.Limburg Maascentr. Nv.Elek.Bed.Zuid-H.Waalhaven Nv Elek.Bed.Zuid-H.Maasvlakte Nv. UNA Centrale Hemweg Nv. UNA Centrale Velsen Nv. UNA Centrale Lage Weide Nv.EPZ Locatie Zeeland Nv.EPON Centrale Gelderland Nv EPON (Centrale Harculo)	5,774 MWh	100%

11.2 Description of processes and sources of fine dust

The most important sources of fine dust emission are the flue gases (concentrated emission) and the handling and storage of coal and residue diffuse emission).

11.3 Emission of fine dust and abatement techniques

The emissions of the power production contribute 3% to the total of industrial emissions.

Source	**Present situation (1998)**				
Sector / process	**PM_{10} share industry**	**PM_{10}**	**$PM_{2.5}$**	**Presently installed abatement technology**	**PM concentration**
Power (40001)	**[%]**	**[ton/y]**	**[ton/y]**		**[mg/Nm^3]**
Process					
Diffuse	0.8	142	14		
Combustion	2.2	397	332	ESP-scrubber-FF	1-10
Total	**3.0**	**539**	**346**		

Flue gases of all oil and coal fired power stations are equipped with flue gas treatment to be able to comply with emission regulations for dust, NO_x, (heavy) metals, dioxins etc..
With a combination of electrostatic precipitation (ESP) and scrubbing and/or fabric filtration the concentrations of (fine) dust in the flue gases of the coal fired power plants are lower than 10 mg/m^3.
NeR/BEES: 20 mg/m^3 (coal), 100 mg/m^3 (heavy oil)

11.4 Further emission reduction

The application of measures to reduce material handling emissions and additional fabric filters to reduce combustion emissions can reduce emissions with 80% and 70% respectively.

12. Refineries (sbi 232)

12.1 Branch description

In refineries, crude oil and natural gas are converted to useful products, such as fuels and raw materials for the chemical industry. The industry is complex, due to the changing composition of feedstock and the broad range of products produced.
The refineries in the Netherlands produce 58 Million tonnes of product per year.

The production of the individually registered companies in the branch.

Refineries		
Company Name	**Annual production Sector 1998 [ton]**	**% of production by individual companies 1998**
Shell Ned.Raff. B.V. Nerefco Europoort Kuwait Petroleum Europoort Bv Esso Nederland Bv Smid En Hollander Raff. B.V. Witco B.V. Total Raffinaderij Ned.Nv	~ 59,000,000	100%

The representativeness of the branch data is high since all companies have been included in the individual registration.

12.2 Description of processes and sources of fine dust

Three processes are the main sources of fine dust emission in oil refineries.

- Distillation of crude oil, primary distillation unit.
- Catalytic cracking/reforming.
- Energy production (electricity and steam).

Primary distillation unit

In the primary distillation unit, crude oil is separated in three fractions, based on boiling point. These three fractions are further processed in the other segments of the refinery. Emissions to air are mainly caused by pressure relief valves, poor containment in overhead systems and venting during cleaning.

Catalytic cracking

Catalytic cracking is the most widely used method to convert larger hydrocarbons to smaller (more useful) molecules. The heavy distillate stream from a distillation section is heated to 500-540°C at 1.5-2.0 bar in the presence of a zeolite catalyst. In this process, coke is formed as a by-product which adheres to the catalysts, resulting in deactivation. The catalyst is regenerated by burning off the coke. This regeneration is the main source of fine dust.

Energy systems

The energy system is one of the most important sources of fine dust emissions in refineries. Fuels are burnt to generate energy, and the emissions depend on the kind of fuel that is used. Heavy fuels cause much more fine dust emission than lighter fuels, because the latter contain much less metal compounds and coke. These compounds are the main source of fine dust.

12.3 Emission of fine dust and abatement techniques

The emissions of the refineries contribute almost 20% to the total of industrial emissions, being the largest PM_{10} and $PM_{2.5}$ emitting industrial sector. The emissions consist of process and combustion emissions.

Source	**Present situation (1998)**				
Sector / process	**PM_{10} share industry**	**PM_{10}**	**PM $_{2.5}$**	**Presently installed abatement technology**	**PM concentration**
Refineries (232)	**[%]**	**[ton/y]**	**[ton/y]**		**[mg/Nm^3]**
Process	9.5	1721	1291	none	50
Diffuse					
Combustion	9.3	1669	1496	none	75-750
Total	**18.8**	**3390**	**2787**		

Primary distillation unit

Particulate matter abatement techniques for the distillation section of refineries are mainly focused on reduction of fuel consumption by using less energy. New developments on abatement techniques include ceramic filters and a rotating particulate separators.

Catalytic cracking

The best technique to reduce fine dust emission during catalyst regeneration is ensuring longer lifetimes for the catalyst. By using ideal conditions, regeneration of the catalyst can be done less often, thereby reducing the amounts of fine dust emitted. In catalytic cracking, particulate emissions can be reduced by retrofitting the existing hot ceramic filters to the underflow of third stage cyclones. In niche applications, use of ceramic filters is possible.

Energy systems

In energy systems, the main focus is on reducing the amount of energy used in the total refinery. By heat integration and more effective production, the energy de-

mand can be reduced, resulting in reduced amounts of fuels that have to be burnt for energy production.
To reduce fine dust emissions in waste gasses several techniques are generally employed:

- Maximize the use of “clean” fuels such as gas and low ash content liquid fuels.
- Steam atomisation on the liquid fuels.
- Use ESP’s or FF in the flue gasses when heavy liquid fuels are used.

12.4 Further emission reduction

Due to fuel switch to natural gas, combustion emissions can be avoided almost totally. This measure has already been agreed upon for the year 2010 (also in relation with greenhouse gas measures). Process emissions can be reduced with 90% by the application of ESP.

13. Rubber & plastic (sbi: 25)

251: Rubber products
252: Plastic products

13.1 Branch description

Rubber: Natural and synthetic rubber is being used in the manufacture of rubber, plastics, carpet and cable. In the rubber processing industry it is mainly used for the manufacture of tires for the transportation sector.

Plastics: The plastics processing industry uses mainly five bulk chemicals (polyethylene, polyvinyl chloride, polypropene and polystyrene) to produce plastic products.

Only four companies are registered in the individual pollutant emission register, together with a dust emission of less than 1 ton/y. The total sector concerns over 1,500 companies. This means that the emission estimate is almost solely based on a collective emission estimate based on emission factors. The representativeness is not known.

13.2 Description of processes and sources of fine dust

Rubber
To give virgin rubber (natural or synthetic) the desired properties (elasticity, hardness, strength) several substances are added during production. The processing of rubber can be divided in three steps: mixing (compounding), moulding and vulcanising. Most emissions of dust occur during compounding.

Plastics
The bulk chemicals for the production of plastics are delivered as fluid, granules or powder.
Handling of powders can give rise to the emission of dust.

13.3 Emission of fine dust and abatement techniques

The emissions of the Rubber and plastics contribute less than 1% to the total of industrial emissions. It concerns diffuse emissions from building ventilation.

Source	Present situation (1998)				
Sector / process	**PM_{10} share industry**	**PM_{10}**	**$PM_{2.5}$**	**Presently installed abatement technology**	**PM concentration**
Rubber & Plastics (25)	**[%]**	**[ton/y]**	**[ton/y]**		**[mg/Nm^3]**
Process					
Diffuse	0.4	66	6	none	0.5
Combustion					
Total	**0.4**	**66**	**6**		

Rubber
The emissions of dust have been reduced by compounding in closed systems and using filters (fabric filters, scrubbers and cyclones).

Plastics
Dust emissions at handling of powders can be reduced by working with dust free concentrates and local ventilation in combination with dust filtration with fabric filters.

13.4 Further emission reduction

Measures to reduce dust emission concern the collection of dust (herewith increasing the concentration of the waste gas flow) and dedusting it with fabric filters. This relatively expensive measure can reach up to 60% emission reduction.

14. Textile (sbi 17, 18)

14.1 Branch description

The textile industry consists of a large number of companies (about 1700) with various types of materials and processing. The textile industry is divided in two sections, with SBI codes 17 and 18. SBI code17 stands for the companies who produce sheets of textile, and 18 stands for the companies who use these sheets to produce clothing.

Only three companies are registered in the individual pollutant emission register, together with a dust emission of less than 1 ton/y. This means that the emission estimate is almost solely based on a collective emission estimate based on emission factors. The representativeness is not known. The total sector concerns almost 5,000 companies.

The total emission of PM_{10} for the production of textile is 121 tonnes per year.

14.2 Description of processes and sources of fine dust

For colouring of textiles, powdered dyes are used. These dyes are dissolved is water or organic solvents. Handling and mixing of dyes causes fine dust emissions, estimated at about 0.05-0.1% of the total use of dyes.

The dust emissions are building emissions with very low fine dust concentrations (typically 1 mg/m^3). Due to this very low concentration, no effective reduction techniques are used at present time.

In the clothing industry, the sheets of textile are used to produce clothes. No process or emissions date are available for this branch of industry.

14.3 Emission of fine dust and abatement techniques

The emissions of the textile industry contribute less than 1% to the total of industrial emissions. It concerns diffuse emissions from building ventilation.

Source	**Present situation (1998)**				
Sector / process	**PM_{10} share industry**	**PM_{10}**	**$PM_{2.5}$**	**Presently installed abatement technology**	**PM concentration**
Textile (17,18)	**[%]**	**[ton/y]**	**[ton/y]**		**[mg/Nm^3]**
Process					
Diffuse	0.7	121	12	none	1
Combustion					
Total	**0.7**	**121**	**12**		

No abatement techniques for the textile industry are used at present time. Due to the low concentrations of fine dust in waste gas streams, no BAT techniques are described.

14.4 Further emission reduction

Measures to reduce dust emission concern the collection of dust (herewith increasing the concentration of the waste gas flow) and dedusting it with fabric filters. This relatively expensive measure can reach up to 80% emission reduction.

15. Waste (sbi: 9000)

15.1 Branch description

There are 11 plants for municipal waste incineration, 2 for hazardous waste, 2 for sewage sludge and 1 for specific clinical waste. Total incinerated waste in 1999 was about 6.000 kton [InfoMil BAT].

The production of the individually registered companies in the branch.

Waste **Company Name**	**Annual production Sector 1998 [ton]**	**% of production by individual companies 1998**
Nv. Afvalverwerking Rijnmond Ruhr-Carbo Milieu Bv GDA-Gem.Dienst Afvalverwerking Nv Avira ARN Bv-Afvalverw.Regio Nijmegen	~ 4,500,000	~ 75%

The representativeness of the branch data is considered to be high since 75% of the sector production has been included in the individual registration.

15.2 Description of processes and sources of fine dust

In the municipal waste incineration sector the grate technology is the most commonly used technology.

Dust emissions occur at the processes:
- pre-treatment, handling and storage of municipal waste (diffuse emission);
- incineration;
- handling of solid residue (diffuse emission).

The flue gasses are the most important source of dust emission. All installations are equipped with flue gas treatment to be able to comply with emission regulations for dust, NO_x, (heavy) metals, dioxins etc.

With a combination of electrostatic precipitation (ESP) and scrubbing and/or fabric filtration the concentrations of (fine) dust in the flue gases of the Dutch incineration plants are 0.5 - 3 mg/m^3 resulting in specific dust emissions of 1-10 g per ton of waste.
NeR/BLA: 5 mg/m^3

15.3 Emission of fine dust and abatement techniques

The emissions of the waste incineration contribute less than 1% to the total of industrial emissions. It concerns mainly combustion emissions.

Source	**Present situation (1998)**				
Sector / process	**PM_{10} share industry**	**PM_{10}**	**$PM_{2.5}$**	**Presently installed abatement technology**	**PM concentration**
Waste (9000)	**[%]**	**[ton/y]**	**[ton/y]**		**[mg/Nm^3]**
Process					
Diffuse					
Combustion	0.2	35	34	ESP-scrubber-FF	3
Total	**0.2**	**35**	**34**		

15.4 Further emission reduction

Measures to reduce dust emission further concern the use of additional fabric filters. This can reduce the sector emissions with 40%.

16. Wood (sbi 20, 361)

Sbi 20: wood processing, production of wooden products
Sbi 361: production of furniture

16.1 Branch description

The branch involves the production of wood (sawmills, production of fibre board, furniture production). The emission estimate is almost solely based upon a collective emission estimate of which the representativeness is not known. The total sector concerns over 3,000 companies.

16.2 Description of processes and sources of fine dust

In the wood processing industry wood dust is generated by sawing, machining operations and by grinding.

16.3 Emission of fine dust and abatement techniques

The emissions of the wood processing industry contribute more than 2% to the total of industrial emissions. It concerns diffuse emissions.

Source	**Present situation (1998)**				
Sector / process	**PM_{10} share industry**	**PM_{10}**	**$PM_{2.5}$**	**Presently installed abatement technology**	**PM concentration**
Wood (20, 361)	**[%]**	**[ton/y]**	**[ton/y]**		**[mg/Nm^3]**
Process					
Diffuse	2.3	406	41	none	1.5
Combustion					
Total	**2.3**	**406**	**41**		

Dust emission is reduced by local extraction and venting systems. The extracted air is passed through fabric filters before discharge. With the vented air from the production buildings diffuse emission of dust takes place.
NeR: 10 mg/m^3.

16.4 Further emission reduction

Measures to reduce dust emission concern the collection of dust (herewith increasing the concentration of the waste gas flow) and dedusting it with fabric filters. This relatively expensive measure can reach up to 90% emission reduction.