Attainability of $PM_{2.5}$ air quality standards, situation for the Netherlands in a European context

This is a publication of the Netherlands Research Program on Particulate Matter

Netherlands Environmental Assessment Agency

BOP report

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J. Matthijsen, PBL; B.A Jimmink, PBL; F.A.A.M de Leeuw, PBL;
W. Smeets, PBL

Netherlands Environmental Assessment Agency

ECN
Energy research Centre of the Netherlands

TNO

rivm
National Institute
for Public Health
and the Environment

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J. Matthijsen, B. Jimmink, F. de Leeuw, W. Smeets
W. Smeets present affiliation is Utrecht Municipality, Department of Environment and Sustainability
Contact: karin.vandoremalen@pbl.nl
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Project assistant: Karin van Doremalen
English editing: Charles Frink, Annemieke Righart
Figure editing: PBL editing and production team
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Cover design: Ed Buijsman (photographer: Sandsun)

ECN Energy research Centre of the Netherlands
PBL Netherlands Environmental Assessment Agency
TNO Built Environment and Geosciences
RIVM National Institute for Public Health and the Environment

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Netherlands Environmental Assessment Agency, (PBL)
PO BOX 303, 3720 AH Bilthoven, The Netherlands;
Tel: +31-30-274 274 5;
Fax: +31-30-274 4479;
www.pbl.nl/en

Rapport in het kort

In 2008 stelde de Europese richtlijn voor luchtkwaliteit normen vast voor de fijnere fractie van fijn stof ($PM_{2,5}$). Nederland is bezig het beleid, de monitoringsmethoden en modellen op het gebied van fijn stof aan te passen om aan de eisen voor $PM_{2,5}$ te voldoen. Dit rapport ondersteunt dat proces met een onderzoek naar de haalbaarheid van de verschillende normen voor $PM_{2,5}$.

Het is waarschijnlijk dat met het huidige en voorgenomen nationale en Europese beleid alle grens- en richtwaarden voor $PM_{2,5}$ op tijd kunnen worden gehaald, bij gemiddelde weersomstandigheden. De $PM_{2,5}$ normen lijken daarmee niet strenger dan de bestaande grenswaarden voor PM_{10}. Deze situatie kan veranderen als in 2013 de Europese richtlijn voor luchtkwaliteit wordt herzien. De onzekerheden in deze beoordeling zijn echter groot. Daarom kan een zeer beperkt aantal overschrijdingen van de 25 µg/m³ richtwaarde langs drukke straten in 2010 niet worden uitgesloten. Ongunstige weersomstandigheden kunnen leiden tot meer overschrijdingen, mogelijk ook van de 25 µg/m³ grenswaarde, in 2015. De blootstellings-reductie-doelstelling (BRD) is een richtwaarde voor de nationaal gemiddelde $PM_{2,5}$-concentratie op stadsachtergrondlocaties tussen 2010 en 2020. De waarde van de BRD in Nederland staat nog niet vast; 15% is het meest waarschijnlijk op basis van de huidige inzichten. Op theoretische grondslag lijkt een BRD van 15% met voldoende significantie gemeten te kunnen worden, gegeven de onderzochte $PM_{2,5}$ monitoringset-up.

Contents

Summary

In 2008, the new European Directive on air quality went into force (EU, 2008b). The new directive combined four existing EU directives, and established air quality standards for fine particulate matter ($PM_{2.5}$). Presently, the Netherlands is in the process of adapting its policy, monitoring methods and models to comply with the requirements for $PM_{2.5}$. To support this process, and to assess the attainability of the various air quality standards for $PM_{2.5}$, this report provides an update of the relevant parts of the earlier assessment that addressed the attainability of proposed $PM_{2.5}$ air quality standards (Matthijsen and Ten Brink, 2007).

It is likely that all limit and target values for $PM_{2.5}$ will be met in time under current and proposed national and European policies, assuming average meteorological conditions. The $PM_{2.5}$ standards appear not to be more stringent than the current PM_{10} limit values. This situation might change when the EU air quality directive will be revised in 2013. Uncertainties in this assessment are large, and our model estimates are believed to have underestimated, rather than overestimated the effect of anthropogenic emission reductions on future $PM_{2.5}$ concentrations. However, it cannot be ruled out that a very limited number of exceedances of the 25 µg/m³ target value may occur along busy streets and motorways in 2010. Even when taking the margin of tolerance for 2010 into account, the resulting value of 29.2 µg/m³ may be exceeded at a very limited number of traffic locations. Meteorological fluctuations may cause additional exceedances, possibly also of the 25 µg/m³ limit value, in 2015. With current national and European policies, the exposure concentration obligation – a limit value for the national average $PM_{2.5}$ concentration at urban background locations – will very likely be met by 2015.

The exposure reduction target (ERT) is a target to reduce the national average $PM_{2.5}$ concentration at urban background locations between 2010 and 2020. There is still uncertainty about the level of the exposure reduction target that will apply to the Netherlands, since this level depends on current and future measured $PM_{2.5}$ concentrations (2009, 2010 and 2011).

Depending on whether or not these measurements exceed, on average, the level of 18 µg/m³, the ERT will be either 15% or 20%. An ERT of 15% seems most probable for the Netherlands, given the present $PM_{2.5}$ urban background concentrations and the current understanding of the concentration changes in the near future. There is question on whether an ERT of 15% can be measured with enough significance since the directive allows a larger uncertainty, up to 25%, in the annual mean $PM_{2.5}$ concentration. For the Netherlands, an ERT of 15% or higher appears to be measurable. It is theoretically possible to measure a statistically significant exposure reduction of 12%, given the current $PM_{2.5}$ measurement network in the Netherlands, the average annual $PM_{2.5}$ concentrations with a measurement uncertainty of 20% and a standard deviation of 18% (due to year-to-year meteorological fluctuations). The effect of possible technical changes in the $PM_{2.5}$ network between 2010 and 2020 has not been taken into account. Such changes can cause uncertainties which make an ERT of 15% no longer measurable.

Current model estimates for $PM_{2.5}$ in 2010 and 2020 show that an ERT of 15% may be attainable with current and proposed national and European policies, but 20% is not. To attain a 20% reduction with the current model, many more policy measures, such as high-efficiency dedusters in the process industry and in refineries, that go beyond present European ambitions need to be taken on both the national and European scale. By themselves, additional national measures will not be sufficient to meet a 20% exposure reduction target. A 20% reduction, however, falls within the relatively large margin of uncertainty.

Meeting the Stage 2 indicative limit value of 20 µg/m³ by 2020 appears to be possible in the Netherlands under current and proposed national and European policies. The indicative limit value will be reviewed by the Commission in 2013.

This assessment was based on model results for 2006, 2010, 2015 and 2020 and available $PM_{2.5}$ measurements, which were obtained with automated monitoring equipment and with instruments operated according to the EU reference method. Emission scenarios for the Netherlands include the current and proposed national emission policies according to Velders et al. (2009). Emission projections for other European countries were taken from Amann et al. (2008).

Our analysis was limited by large uncertainties in the models and measurements. On the one hand, our model estimates are believed to have underestimated, rather than overestimated, the effect of anthropogenic emission reductions on future $PM_{2.5}$ concentrations. This means that larger relative reductions, resulting from current and proposed national and European policies, even up to

20%, are within the margin of uncertainty. Furthermore, concentrations at hot-spot traffic locations may have been somewhat overestimated for 2010, partly due to the effect of the current economic recession, which was not included in our analysis. On the other hand, $PM_{2.5}$ concentration levels and the trend are not well understood in terms of sources and dispersion; consequently more pessimistic developments can not be excluded as yet. In addition, the basic assumption in our analysis, that all Member States will comply fully with their future national emission ceilings for 2020, may prove to be optimistic.

1 Introduction

The new *Commission Directive 2008/50/EC on ambient air quality and cleaner air for Europe* came into force on 11 June 2008 (EU, 2008b). The directive combined four existing EU air quality directives (the Framework Directive and the 1st, 2nd and 3rd Daughter Directives); among other things, it also established new air quality standards for fine particulate matter ($PM_{2.5}$ – see Table 1). An average annual $PM_{2.5}$ concentration of 25 µg/m³ has been set as the target value for 2010 and as the limit value to be met by 2015. The new directive also introduced additional $PM_{2.5}$ objectives, which aim to reduce human exposure to $PM_{2.5}$. Standards are set at the national level and are based on the average exposure index (AEI). The AEI is a three-year average $PM_{2.5}$ concentration level, measured at urban background locations across each Member State.

For this report we investigated the attainability of the $PM_{2.5}$ limit and target values for the Netherlands. The main questions were:

- Can the air quality standards set for $PM_{2.5}$ be met with technical emission control measures under current and proposed national and European policies?
- What is the impact of different European emission reduction scenarios (Amann *et al.*, 2008) on the attainability of the $PM_{2.5}$ standards?
- What is the effect of additional national and European policy measures on the attainability of the $PM_{2.5}$ standards?

These questions were addressed for the situation in the Netherlands, while taking account of the situation in other European countries and the uncertainties.

To address these questions, knowledge on concentration levels in the 2010-2020 timeframe was needed, as well as on the effects of various abatement policies. This knowledge was derived from both models and measurements. Estimates of future $PM_{2.5}$ concentrations were made using measured, current levels, together with model calculations, to assess future concentration changes, taking into account the effects of different abatement policies.

This report can be seen as an update and extension – with the focus on attainability – of an initial assessment by Matthijsen and Ten Brink (2007) (hereafter called MtB2007). Updated information with regard to other $PM_{2.5}$ topics, such as source apportionment and the contribution of different components to the $PM_{2.5}$ mass, have been addressed in other reports which resulted from the BOP research program (BOP, 2007). The main conclusions on attainability of the $PM_{2.5}$ standards in MtB2007 are presented in the text box below.

An update of the MtB2007 assessment was necessary for the following four reasons:

Limit values and target values for $PM_{2.5}$ for EU Member States according to the air quality directive (EU, 2008b) **Table 1.1**

Limit values	
25 µg/m³	2015 for the average annual concentration; applies everywhere*
20 µg/m³	2015 for the AEI**. In the EU directive, this value is referred to as exposure concentration obligation (ECO). The ECO has the same juridical status as a limit value, so it is referred to as a limit value in this report.
20 µg/m³	2020 for the average annual concentration; applies everywhere*. This is a so-called Stage-2 indicative limit value, to be reviewed by the Commission in 2013.
Target values	
25 µg/m³	2010 for the average annual concentration; applies everywhere
0 - 20%	exposure reduction target (ERT) for 2020, relative to 2010 of the AEI**

* While these limit values apply throughout the country, compliance shall not be assessed at the following locations: any locations situated within areas where members of the public have no access and there is no fixed habitation; on factory premises or at industrial installations; on the carriageway of roads and on their central reservations of roads except where there is normally pedestrian access to the central reservation.
** The indicator for the average urban background concentration is the average exposure index (AEI). The AEI is the three-year average of measured average annual $PM_{2.5}$ concentrations at urban background locations. The national exposure reduction target value depends on the initial concentrations; the ERT value ranges from 0% (when the initial AEI is below 8.5 µg/m³) to more than 20% when the initial AEI exceeds 22 µg/m³. In the Netherlands, present estimates of $PM_{2.5}$ concentrations indicate that urban background levels are around 18 µg/m³. Therefore, the Netherlands faces two possible exposure reduction target values: 15% when the AEI for 2010 falls in the range of 13 to 18 µg/m³ and 20% between 18 to 22 µg/m³.

1. The final set of $PM_{2.5}$ standards established by the new air quality directive differs from the set of standards on which MtB2007 was based.
   - The directive introduced the *exposure concentration obligation*, a limit value of 20 µg/m³ for the AEI, to be met by 2015.
   - Altered margins were set for the AEI for 2010. These AEI margins determine the national exposure reduction target.
   - The limit value for the average annual concentrations to be met by 2015 was set at 25 µg/m³. At the same time, 25 µg/m³ was set as a target value for 2010. Until 2015, exceedances are allowed within the margin of tolerance. Note that, in 2007, a more stringent limit value of 20 µg/m³ was negotiated.
   - A Stage 2 indicative limit value of 20 µg/m³ has been introduced in the final directive, applying to average annual concentrations for 2020. This indicative limit value is to be reviewed by the Commission in 2013 in the light of further information on health and environmental effects, technical feasibility, and experience with the target value in Member States.
2. More measurement results on $PM_{2.5}$ and PM_{10} concentrations have become available, both within the Netherlands and in other Member States. These measurements formed the starting points for the new assessment.
3. In December 2008, an agreement was reached at EU level on the climate and energy package proposed by the Commission in December 2007. MtB2007 stressed that planned national and European legislation to mitigate climate change should also be integrated in updated assessments, because they can affect particulate-matter levels.
4. Several air quality policy developments were taken into account in the present analysis, including the agreement of the International Maritime Organization (IMO) (October 2008) on cleaner fuels and engine requirements for sea

Netherlands Research Program on Particulate Matter (BOP)

This study was conducted under the auspices of the Netherlands Research Program on Particulate Matter (BOP), a national program on PM_{10} and $PM_{2.5}$, funded by the Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM). The programme is a framework of cooperation involving four Dutch institutes: the Energy research Centre of the Netherlands (ECN), the Netherlands Environmental Assessment Agency (PBL), the Environment and Safety Division of the National Institute for Public Health and the Environment (RIVM), and TNO Built Environment and Geosciences.

The goal of BOP is to reduce uncertainties about particulate matter (PM) and reduce the number of policy dilemmas, which complicate the development and implementation of adequate policy measures. Uncertainties about the health aspects of PM are not explicitly addressed.

The approach for attaining these objectives involves the integration of mass and composition measurements of PM_{10} and $PM_{2.5}$, emission studies and model development. In addition, dedicated measurement campaigns were conducted to research specific PM topics.

The results from the BOP research programme are being published in a special series of reports. The topics in this series, in general terms, are the following: sea salt, mineral dust, secondary inorganic aerosol, elemental and organic carbon (EC and OC), and mass closure and source apportionment. Some BOP reports concern specific PM topics: urban background concentrations, PM trend, shipping emissions, EC and OC emissions from traffic, and attainability of $PM_{2.5}$ standards (this report). Technical details of the research programme will be condensed in two background documents; one on measurements and one on model developments. In addition, all results will be combined in a special summary for policymakers.

Main conclusions of the initial assessment on $PM_{2.5}$ in the Netherlands, as presented in MtB2007

For the Netherlands, the available data on current and future levels of $PM_{2.5}$ suggested that the limit value of 25 µg/m³ can probably be attained by 2015, apart from in a very limited number of hot spots. The strictest limit value for PM_{10} concerns 24-hour concentrations, which are not to exceed 50 µg/m³ more than 35 times per calendar year. This limit value appears to be more stringent than the $PM_{2.5}$ limit value of 25 µg/m³.

Target value: a reduction of 15% of the AEI (exposure in urban areas) between 2010 and 2020 will probably not be reached under current legislation. A reduction of 20% will almost certainly not be reached under current legislation, even with proposed additional measures. In case a 20% reduction is required, additional national and local measures, and possibly European measures, may be necessary.

In other EU Member States

In other densely populated and industrialised regions in Europe, attainability problems regarding the $PM_{2.5}$ limit value of 25 µg/m³ appear to be similar to those in the Netherlands. However, it is unclear whether the relevant Member States will face similar problems meeting an exposure reduction target of 20%, because the level of implementation of technical and non-technical reduction measures differs throughout Europe, and measurements of $PM_{2.5}$ are scarce.

shipping, the Euro-VI standards for heavy-duty vehicles and several national air quality measures. As model input, updates of the national emission scenarios were applied for the Netherlands (Velders *et al.,* 2009), and for other European countries the emission scenarios reported in Amann *et al.* (2008) were used.

The $PM_{2.5}$ results in this report are rather uncertain (at least ±20% 2 sigma: 95% confidence limits). These uncertainties stem from uncertainties about measurements, models and emissions. Furthermore, scenario studies were based on several assumptions that largely determined the results. For instance, we used an add-on concentration, fixed in time, to describe the contribution to $PM_{2.5}$ from natural sources and sources that are not explicitly included in the model. In addition, all emission scenarios analysed in this report assume that EU Member States will comply with their national emission ceilings set for 2010. The current economic downturn will probably help to make this assumption more realistic. However, whether the newly drafted national emission ceilings for 2020 will be complied with in time, by all EU Member States, remains uncertain.

The following is a general outline of the report:

Chapter 2, *Current $PM_{2.5}$ levels,* presents a summary of available information on current $PM_{2.5}$ concentration levels in the Netherlands and Europe. The current levels were the starting point for the attainability analysis in this report. The uncertainties in $PM_{2.5}$ measurements have been put into the context of the requirements brought about by the $PM_{2.5}$ standards.

Chapter 3, *Current and proposed policies,* provides a description of the different national and European emissions and emission scenarios that were used as input for the model experiments, in addition to current legislation and the NEC-6 scenarios. In order to investigate further options, composite scenarios and the Maximum Reduction Range scenario have been described.

Chapter 4, *Approach,* presents an elaboration on the methodology that was followed to assess the attainability of the new $PM_{2.5}$ standards. The conclusions on the attainability have been put into the context of the uncertainties in $PM_{2.5}$ model results.

Chapter 5, *Distance to $PM_{2.5}$ targets,* presents the results from the assessment for the Netherlands and compares them to the situation in other Member States.

Chapter 6, *Additional measures,* provides a shortlist of national and international policy actions for reducing PM-related emissions and their effect on $PM_{2.5}$ concentration levels.

Chapter 7, *Conclusions,* gives a summary of the overall results, and comments on shortcomings caused by uncertainties.

Current levels of $PM_{2.5}$

2

In order to report on the attainability of the $PM_{2.5}$ standards, current levels of $PM_{2.5}$ had to be ascertained, and could then be used as a starting point. The ranges for $PM_{2.5}$ in the Netherlands and abroad, as reported in MtB2007, have been updated here with recent information.

Throughout Europe, the knowledge on current $PM_{2.5}$ concentration levels is still rather limited. Many Member States have only recently started to include $PM_{2.5}$ measurements in their national air quality monitoring networks. Routine measurements of $PM_{2.5}$ using automated samplers are thought to be more uncertain than measurements of PM_{10} because the semi-volatile PM fraction, which is a main source of measurement uncertainty, resides predominantly in the fine fraction. Consequently, the climatology of $PM_{2.5}$ in the Netherlands is not yet well understood. In this section we report on the current $PM_{2.5}$ levels in the Netherlands and the rest of Europe.

2.1 Levels in the Netherlands

In 2004, monitoring of $PM_{2.5}$ started in the Dutch National Air Quality Monitoring Network (LML, 2008). In addition to this national monitoring network, $PM_{2.5}$ is also monitored in the Netherlands by the local networks in Amsterdam and in the Rotterdam area. Since 2002, these local networks have reported average annual $PM_{2.5}$ concentrations (GGD Amsterdam, 2008; DCMR, 2008). Measurements provided by the networks for the 2002-2005 period concerned mostly raw data, in the sense that no equivalence factor was established or applied. Such an equivalence factor can be used to translate raw data into values which would be obtained with the reference method. Raw $PM_{2.5}$ data (without application of an equivalence factor) has limited value for determining the $PM_{2.5}$ levels.

In 2006, $PM_{2.5}$ measurements with the EU reference method were started in the Netherlands. Since 2007, some of these measurements have been obtained as a result of the BOP program. The reference method for sampling and measuring $PM_{2.5}$ is described in EN 14907:2005 'Standard gravimetric measurement method for the determination of the $PM_{2.5}$ mass fraction of suspended particulate matter'. Figure 2.1 shows a range of $PM_{2.5}$ measurements for the Netherlands, as obtained with the reference method in 2006, 2007 and 2008.

The data shown in Figure 2.1 have been subdivided according to rural, urban and traffic locations. The number of measurement stations per year is shown below the figure. The concentration ranges for 2006 and 2007 should be interpreted cautiously; the representativeness of the ranges is small due to the limited number of measurements and monitoring locations. Furthermore, the absolute value probably contains a bias of up to several µg/m³ due to water adsorption (see *Measurement uncertainty* in this chapter). The $PM_{2.5}$ concentration ranges for 2008 (Hoogerbrugge, in preparation) are more reliable due to the following modifications in the procedure:

1. A bias due to water adsorption on the quartz filter was minimised due to a more stringent measurement protocol in the Netherlands for the reference method (NTA 8019).
2. The number of rural and urban stations was large enough to establish a representative range.
3. Data coverage over the year was optimised by using multiple imputation technique, a method for correcting the average annual concentration for missing data. This technique has not yet been applied to the $PM_{2.5}$ measurement series for 2006 and 2007.

Levels at rural locations

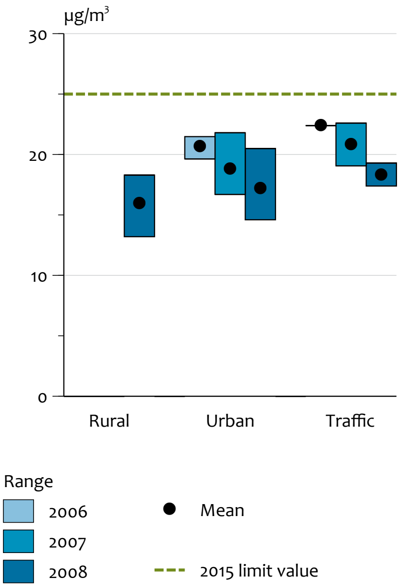
$PM_{2.5}$ concentrations at the rural sites in 2008 ranged between 13 and 18 µg/m³. This range was 12 to 16 µg/m³ in MtB2007. Generally speaking, the $PM_{2.5}$ levels measured at the nine rural locations were similar to levels at urban background locations. A relatively small increment from rural to urban background locations was in accordance with a recent study on urban background concentrations in the Netherlands (Voogt *et al.*, 2009).

Levels at urban background locations

Concentrations at urban agglomerations were especially interesting because they served as input for deriving the average exposure index. The range found for average annual $PM_{2.5}$ concentrations in 2008 was 15 to 21 µg/m³. A similar range of 17 to 22 µg/m³ was inferred from routine PM_{10} measurements at urban background locations and extrapolated $PM_{2.5}$ to PM_{10} ratios. Compared to the indicative urban background levels (16 to 19 µg/m³) given by MtB2007, the ranges reported here were higher at the top and lower at the bottom. These data suggest that the concentration increment in urban background areas with respect to rural background concentrations (the urban increment) was relatively small; less than 2 µg/m³.

$PM_{2.5}$ measurements **Figure 2.1**

Average annual concentration



Number of stations

	Rural	Urban	Traffic
2006	-	3	1
2007	-	4	2
2008	9	10	6

Concentration ranges for average annual $PM_{2.5}$ (µg/m³) in 2006, 2007 and 2008, based on measurements in the Netherlands taken with the reference method by the RIVM, the Public Health Service Amsterdam and the Rotterdam Environmental Protection Agency.

Levels at urban traffic locations

$PM_{2.5}$ concentrations measured in 2008 at traffic locations in the Netherlands ranged between 17 and 19 µg/m³. These location levels appeared to be relatively low compared to rural and urban background levels, and were at the lower end of the range of the levels reported for traffic locations in other populated regions in Europe. $PM_{2.5}$ concentrations which have been inferred from routine PM_{10} measurements at traffic locations and observed $PM_{2.5}$ to PM_{10} ratios of 0.59 (see Table 2.1) point towards higher $PM_{2.5}$ levels, up to 23 µg/m³, at these locations. Therefore $PM_{2.5}$ concentrations along motorways and streets may even exceed 25 µg/m³, but the number of locations where this may occur is probably limited.

Average Exposure Index

The average exposure index (AEI) is a measure for $PM_{2.5}$ introduced in the EU air quality directive. The AEI is the indicator for the average urban background concentration of particulate matter. The rationale for the introduction of such an indicator was that epidemiological research cannot identify a no-effect level for particulate matter. This means that health effects may be expected at all PM levels. Consequently, from a health point of view, it makes sense to reduce particulate matter levels on large spatial and temporal scale. The AEI is a good indicator for this purpose. In the Netherlands, twelve locations have been selected to measure urban background $PM_{2.5}$ concentrations (see Figure 2.2) for the purpose of determining the AEI. The AEI is used for determining whether the exposure concentration obligation (ECO) and the exposure reduction target (ERT) have been met. The ECO and ERT standards both concern three-year average urban background concentrations and do not have to be met everywhere, in contrast to the other $PM_{2.5}$ standards.

The exposure reduction target has 2010 as the reference year. The Netherlands has opted for the average concentration levels of 2009, 2010 and 2011 as the starting point, instead of those of 2008, 2009 and 2010, or 2009 and 2010.

The set of $PM_{2.5}$ measurements that we obtained with the reference method was too small to calculate an 'official' average exposure index.

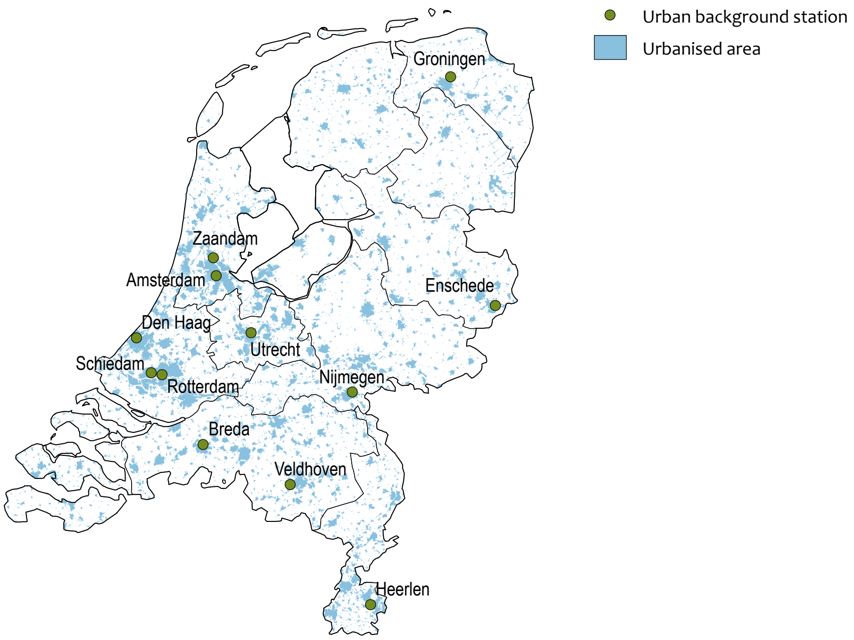
Monitoring $PM_{2.5}$ according to the directive guidelines

At present, the Dutch national Air Quality Monitoring Network (LML), operated by the RIVM, includes $PM_{2.5}$ measurements at urban background locations obtained with the reference method, starting in 2008. This takes place in cooperation with the local networks of Amsterdam and Rotterdam. To calculate the average exposure index (AEI), $PM_{2.5}$ measurements were used from twelve urban background locations (see Figure 2.2). Eight of these twelve locations are required by the guidelines in the new air quality directive for the specific situation in the Netherlands, and four additional urban background locations were chosen to increase the spatial coverage.

The final number of traffic and rural $PM_{2.5}$ measurement locations is yet to be decided upon. In the future $PM_{2.5}$ will also be measured with automated monitoring instruments besides with reference instruments. The automated measurements will be carried out with Beta-Attenuation monitoring instruments in the national network, as well as in

Urban background stations for average exposure index, AEI

Figure 2.2



Urban background locations in the Netherlands which have been selected for $PM_{2.5}$ measurements used to derive the average exposure index (AEI).

several regional measurement networks. For this instrument, equivalence has been found with the reference method (van Arkel *et al.,* 2008).

Measurement uncertainty

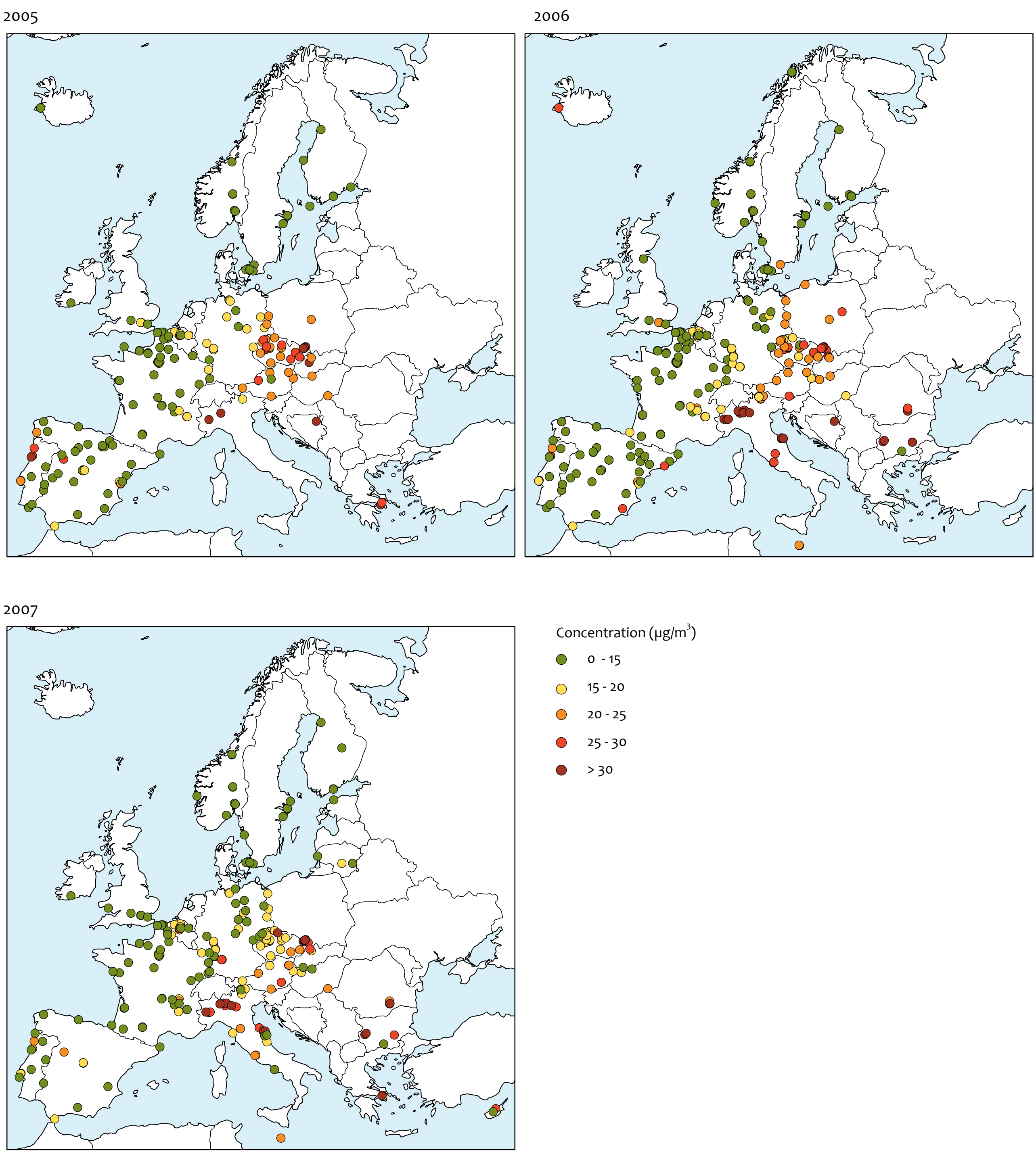
The conclusions drawn from the current $PM_{2.5}$ levels in this chapter were based on measurements obtained with the reference method using quartz filter material. Although these measurement results were uncertain (typically 20%, 2 sigma), this uncertainty was generally smaller than that in measurement results from automated PM samplers which dry the air before sampling. Reference measurements that were performed according to the guidelines still allowed considerable variation, as in choice of filter material.

The use of different types of filters per Member State complicates the comparability of levels between Member States and air quality networks. Quartz-fibre filters adsorb water vapour during collection of particulate matter, and part of this water is retained during drying. This adsorbed water vapour was then erroneously counted as water associated with PM (e.g. Maggs *et al.,* 2009; Brown *et al.,* 2006). Adsorption of volatile organic carbon on quartz filters can introduce a bias in a similar way and of similar magnitude (e.g. Ten Brink *et al.,* 2009). In 2007, the managers of air quality networks in Netherlands agreed on a measurement protocol that defines the reference method in greater detail (NTA 8019). Since 2008, the various networks have been using the same quartz filters and the same protocol for the preparation of quartz filters, for reference measurements. The protocol for quartz filter preparation aims to improve quality assurance and minimisation of a possible bias due to adsorbed water vapour. A similar bias due to adsorbed volatile OC is not specifically addressed in the measurement protocol. Only some of the measurements reported here were conducted under the more stringent national EN guidelines (12341, 12907), so some series may have contained a substantial bias due to water and OC adsorption (2006, 2007 in Figure 2.1). A bias due to water adsorption in the ranges for 2008 (Figure 2.1) was believed to be negligible.

Uncertainty requirements in relation to the exposure reduction target

European regulations allow a maximum uncertainty of 25% (2 sigma) in the measured data, but the national exposure reduction target for the Netherlands will be 15% or 20%. Since the allowed uncertainty in the measurements is larger than the exposure reduction target it appears that a reduction of this magnitude will not be easily measurable.

We estimated that for the measurement set-up in the Netherlands, an AEI reduction of about 12% or more could be determined as statistically significant (α=0.05, tested one-sidedly). For details, see the text box below. In principle, therefore, an AEI reduction of 15 or 20% could be determined as statistically significant. There are, however, other technical issues which may complicate the accountability of the AEI-related $PM_{2.5}$ standards, such as the question of whether the urban background location was representative of the urban background concentrations.



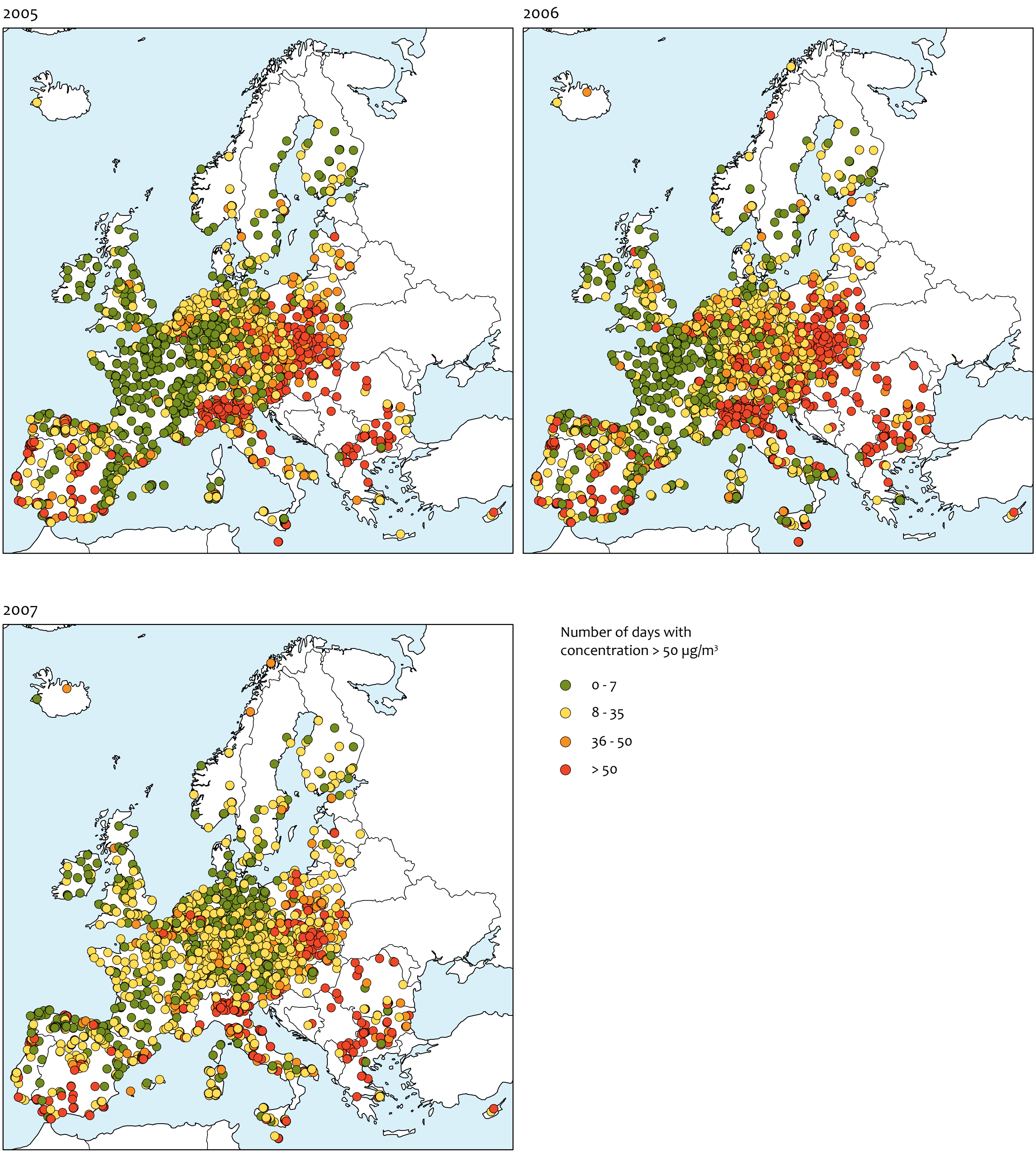
Average annual $PM_{2.5}$ concentrations in 2005, 2006 and 2007 from AirBase stations (rural, urban and traffic) with data coverage of more than 75%. Source: AirBase.

2.2 Levels in Europe

Most EU Member States have started measuring $PM_{2.5}$ to comply with the requirements in the 1st Daughter Directive on Ambient Air Quality (EU, 1999). In this context, data have been reported to the European Environment Agency (EEA), which has placed the data in the public database AirBase (AirBase, 2009; Mol *et al.*, 2009).

For 2007, the number of $PM_{2.5}$ measurement series reported to AirBase was about seven times smaller than those available for PM_{10} (see the maps for $PM_{2.5}$ and PM_{10} in Figures 2.3 and

PM_{10} exceedance days **Figure 2.4**



PM_{10} in 2005, 2006 and 2007, from AirBase measurements (rural, urban and traffic locations) with data coverage of more than 75%. Number of days with concentrations above the 50 µg/m³ limit value. Source: AirBase.

2.4). About two thirds of the countries that report data on PM_{10} concentrations also do so for $PM_{2.5}$. Consequently, although the basis for an assessment of $PM_{2.5}$ levels, Europe wide, is still rather small, the AirBase data showed that in several countries the current concentrations were higher than the 2015 limit value of 25 µg/m³, with some even higher than 30 µg/m³ (see Figures 2.3 and 2.5).

Exceedances of the 25 µg/m³ and 30 µg/m³ levels occurred specifically in highly industrialised regions in central Europe and at urban sites in southern Europe. It is obvious that there were even more sites at which the indicative limit value for 2020 of 20 µg/m³ was exceeded. In Germany, for instance, the current levels at the higher end were about 25 µg/m³. Low levels were typically found in the less populated countries of northern Europe. Data from the Netherlands were not yet available in AirBase, but are presented above (Figure 2.1).

The value of this $PM_{2.5}$ data is rather uncertain, because most of these were not obtained according to the official measuring guideline, but from automated monitors; in general, these monitors systematically underestimate the levels. In 2006, about 70% of the $PM_{2.5}$ measurements officially reported were obtained with automated monitoring instruments for which equivalence had to be proven with the reference method (for example, see Vixseboxse and De Leeuw, 2008). For $PM_{2.5,}$ it is uncertain to what extent these data had been corrected to establish equivalence. The PM_{10} and $PM_{2.5}$ data available from AirBase were used without any further processing. We assumed that, where needed, the PM data had been corrected for a non-reference method in accordance with the EU directive's requirements (Exchange of Information, EoI; EC, 1997).

Because the EoI requires the countries to submit validated data, information on PM_{10} methods and correction factors was given by Buijsman and De Leeuw (2004) and De Leeuw (2005), but this information was not up to date. Information on the applied $PM_{2.5}$ correction factors was not available. Some information, although still incomplete, on PM correction factors was available from the reporting questionnaire under the Air Quality Framework Directive (see Vixseboxse and De Leeuw, 2008).

The ratio of $PM_{2.5}$ to PM_{10} concentrations

The ratio of $PM_{2.5}$ to PM_{10} is important, because of the stringent legislation on the two parameters. The ratio also could be used to infer $PM_{2.5}$ levels from PM_{10} concentrations, which were more abundant (see Section 5.2).

Average $PM_{2.5}$ to PM_{10} ratios (Table 2.1) were derived from AirBase co-located $PM_{2.5}$ and PM_{10} measurements, extracted for the 2004-2006 period (see De Leeuw and Horalek, 2009). The ratios were in the range of 0.4 to 0.8. In northern and central eastern Europe there was a clear tendency towards lower ratios in the declining order of rural to urban to traffic. This indicated an increasing contribution of locally emitted coarse particles at urban and traffic sites. In north-western

The statistical significance of an AEI reduction using reference measurements

The following describes a test to determine whether a significant reduction in the average exposure index (AEI) could be measured (α=0.05).

In the Netherlands the AEI is monitored at twelve urban background stations with instruments that measure $PM_{2.5}$ according to the reference method (EN-14907:2005). The uncertainty in the average annual $PM_{2.5}$ concentration was estimated to be about 10% (1 sigma). Meteorological fluctuations are another source of uncertainty. Velders and Matthijsen (2009) found that average annual PM_{10} concentrations have a standard deviation (SD1) of about 9% (1 sigma), from year to year, due to meteorological fluctuations. We assumed the same for $PM_{2.5}$, since $PM_{2.5}$ and PM_{10} are strongly correlated in time. The standard deviation, SD2, due to the measurement uncertainty in the average annual urban background concentration at 12 stations then becomes about 3% (0.10/√12). Since both sources of variance are uncorrelated, the overall standard deviation ($SD = \sqrt{SD1^2 + SD2^2}$) would be about 9.5% ($\sqrt{0.03^2+0.09^2}$) for any year.

The AEI is defined as the three-year running average annual urban background concentration. Averaging over three years reduces the standard deviation by a factor of √3. Consequently, we estimated a standard deviation of the AEI of about 5.5% (0.095/√3) for any set of three years. The AEI for 2020 (AEI_{2020}) and 2010 (AEI_{2010}) are not correlated. Therefore, the standard deviation, SDΔ, of the difference, $\Delta = AEI_{2010} - AEI_{2020}$, is simply:

$$SD\Delta = 0.055\sqrt{AEI_{2010}^{\ 2} + AEI_{2020}^{\ 2}} \qquad (1)$$

The AEI for 2020 is significantly (α=0.05) smaller than for 2010, when:

$$AEI_{2010} - AEI_{2020} \geq \varepsilon\ SD\Delta \qquad (2)$$

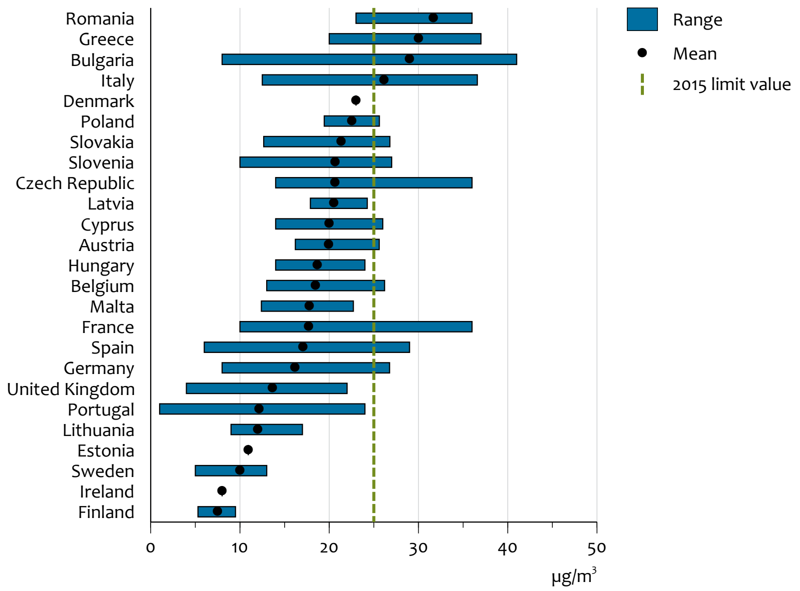
where ε = 1.65, when α=0.05 is tested one-sidedly, which means that significance tested for AEI_{2020} is lower than for AEI_{2010}. For a two-sided test ε = 2. When we assume an AEI reduction of about 15%, equations 1 and 2 become:

$$AEI_{2010} - AEI_{2020} \geq 1.65 \times 0.055\ AEI_{2010}\sqrt{1.85} \approx 0.12\ AEI_{2010} \qquad (3)$$

Which means that the measured relative difference, $(AEI_{2010} - AEI_{2020})/AEI_{2010}$, should be larger than about 12% to be significant (α=0.05, tested one-sidedly). This result is rather insusceptible to uncertainty in the $PM_{2.5}$ measurement, because the main source of uncertainty is introduced by year-to-year meteorological fluctuations. The data quality objectives in the directive allow a maximum uncertainty level of 12.5% (1 sigma) in the measured average annual $PM_{2.5}$ concentration. If the measurement uncertainty were 20% (1 sigma) instead of 10%, then the significance level would increase from 12 to 14% (α=0.05, tested one-sidedly).

Note that there are other sources of uncertainty which were not included in this test; these are caused by aspects such as limited data coverage. Nevertheless, the results presented here appear to be quite robust. The significance of an AEI reduction based on reference measurements is a topic currently being addressed by the association of National Air Quality Reference Laboratories (AQUILA). AQUILA is a formally established network - open to all of the National Reference Laboratories across Europe - that verifies and supports the correct implementation of air quality directives in Europe (AQUILA, 2009).

Annual $PM_{2.5}$ concentration, 2007 — Figure 2.5



Annual $PM_{2.5}$ concentration range, minimum, maximum and average, per EU country for 2007. The range consists of measurements at rural, urban background and traffic locations, with data coverage of more than 75%. Note that not all EU countries have reported $PM_{2.5}$ data for 2007.

Average $PM_{2.5}$ to PM_{10} ratios for Europe, per region and per station type — Table 2.1

	$PM_{2.5}$ to PM_{10} ratio			number of time series		
Region	**Rural**	**Urban**	**Traffic**	**Rural**	**Urban**	**Traffic**
northern	0.78	0.55	0.42	5	11	6
north-western	0.53-0.69*	0.63	0.59	8	78	32
central eastern	0.75	0.71	0.65	20	73	41
southern	0.57-0.64*	0.58	0.53	48	39	38
Europe	0.62	0.65	0.58	81	201	117

* Adjusted ratio, see above text.

and southern Europe, there was no such tendency. The rural stations in north-western Europe had a ratio which was surprisingly low compared to the ratio at urban and traffic sites in this region. The low number of time series may have played a role here: only eight rural time series (six in the United Kingdom and two in Belgium) were available, whereas the urban time series were measured mostly in France (64 from the 78 time series in total). In southern Europe, the rural background stations were mostly located on the Iberian Peninsula (45 from the 48 time series in total). A possible explanation for the low rural ratio in this region might be an important contribution of mineral (Sahara) dust.

The representativeness of the rural ratio in the north-western and southern regions is questionable. Therefore, the differences between a rural station and a nearby (less than 75 km) urban background station were examined in a more detailed analysis (De Leeuw and Horalek, 2009). Only 17 rural stations were linked with one or more urban background stations within the required distance. On average, the $PM_{2.5}$ to PM_{10} ratio at a rural background station would be 10% higher than at the nearby urban stations. The rural ratios in the north-western and southern regions were therefore adjusted by 10%.

Current emission scenarios

3

In order to achieve lower PM levels, policies to mitigate emissions were developed at both the European and national levels. This chapter describes the various policy scenarios that were used throughout this report. These scenarios were used to analyse the likeliness of achieving air quality standards for $PM_{2.5}$ in the future, as described in Chapter 1. The various scenarios were developed by the International Institute for Applied Systems Analysis (IIASA) during the revision of the Directive on National Emission Ceilings (NEC) (Amann *et al.*, 2008) by applying the GAINS model. This model can generate integrated evaluations of emissions across the entire chain, from source to effect and the reverse, as well as generating mitigation scenarios. The GAINS model was used to construct cost-optimised emission reduction scenarios (achievement of EU-wide targets as set out in the Thematic Strategy, at the least cost to the EU as a whole).

The NEC directive revision process should lead to a proposal from the European Commission for national emission ceilings for 2020. The revision process is presently pending.

3.1 Emission scenarios

The policy scenarios presented in this study are the result of various optimisation runs with the GAINS model of IIASA (Amann *et al.*, 2008). These scenarios portray the possible future development of emissions, given a specific central baseline projection for economic activities, traffic, energy use and agricultural activities. The baseline projection was based on energy projections that include the recent Climate and Energy Package of the European Commission (see, for instance, Olivier *et al.*, 2008) and the national projections of agricultural activities. Amann et al. (2008) examined cost-effective emission ceilings for the air pollutants sulphur dioxide (SO_2), nitrogen oxides (NO_x), primary $PM_{2.5}$, ammonia (NH_3) and volatile organic compounds (VOC). Compliance with emission ceilings for 2020 for these pollutants – all of which contribute to $PM_{2.5}$ – will lead to achieving the environmental objectives of the Thematic Strategy on Air Pollution (CEC, 2005).

The scenarios assessed in this study consisted of three types of emission sources: land-based emissions for the Netherlands, land-based emissions for other European countries and North Sea emissions from international shipping (see Table 3.1 and Table 3.2). Emissions for land-based sources in the Netherlands were in line with the RGE and BGE emission scenarios that have been developed as part of the Dutch National Air Quality Programme (Velders *et al.*, 2009). More details on the primary $PM_{2.5}$ emissions that are specific to the Netherlands can be found in Annex A. Emissions for the rest of Europe and for international sea shipping were based on the so-called NEC-6 emission scenarios as given in the sixth analysis report on National Emission Ceiling scenarios, as developed by IIASA for the European Commission (Amann *et al.*, 2008).

The emission figures for the Netherlands from the RGE and BGE emission scenarios that were used for this report may deviate from emission figures for the Netherlands in the corresponding emission scenarios reported by IIASA in its

Overview of emission scenarios used for the evaluation of the $PM_{2.5}$ air quality standards **Table 3.1**

Emission scenario	Year	The Netherlands[1)]	Rest of Europe[2)]	International Shipping[2)]
CP	2010/2020	RGE	Current Policies	No further control
TSAP	2020	BGE	TSAP Central Case	No further control
EP	2020	BGE	European Parliament	No further control
IMO	2020	BGE	TSAP – after international shipping measures	IMO[3)]
MRR	2020	Maximum Reductions	Maximum Reductions	IMO

1) RGE and BGE are according to Velders *et al.*, 2009
2) EU-27, according to Amann *et al.*, 2008
3) North Sea only, according to IMO, 2008.

Emission totals (kilotonnes) for the EU27, for the different policy scenarios

Table 3.2

Year	scenario	SO_2	NO_x	$PM_{2.5}$	NH_3	VOC
2000		10,352	12,155	1,857	4,020	10,867
2010	CP	8,297	9,003		4,294	8,848
2020	CP	2,924	5,684	1,263	3,709	6,146
2020	TSAP	2,336	5,158	1,006	3,139	6,072
2020	IMO	2,700	5,290	1,054	3,176	6,077
2020	EP	1,938	4,838	957	3,079	5,523
2020	MRR	1,755	4,446	655	2,394	4,138

Emission totals (kilotonnes) for the EU27, for the different policy scenarios in 2020, the emissions in 2010 according to the Current Policies scenario, and emissions in 2000 (Amann et al., 2008). Note that under the EP emission scenario, EU27 totals are smaller per component than under the IMO emission scenario: -28% (SO_2), -9% (NO_x), -9% ($PM_{2.5}$), -3% (NH_3) and -9% (VOC).

NEC-6 report; these sources were not fully consistent. The national emission estimates were used, instead of those according to Amann et al. (2008), to facilitate comparability with the results from the Dutch National Air Quality Monitoring Network (e.g. Velders *et al.*, 2008; Velders *et al.*, 2009). However, the differences between the approaches are negligible with respect to the overall conclusions.

Current Policies, CP

The Current Policies scenario (CP) projects emissions for 2010 and 2020, resulting from the increasing implementation of current and proposed emission control measures. In addition, compliance with current National Emission Ceilings, from 2010 onwards, was assumed. Also included were the recent proposals for additional European emission legislation, that is, the introduction of EURO-VI standards for heavy-duty vehicles (EU, 2008c) and the revision of the Integrated Pollution and Prevention Control Directive for large stationary sources (EU, 2008a; IIASA, 2008). The Dutch RGE scenario includes all current measures, as well as current international and national policies.

To keep the analysis for the CP emission scenario consistent with Amann *et al.* (2008), no further controls on the emissions from international maritime shipping were included in this CP scenario. However, the scenario included the International Maritime Organization's agreement with new reduction limits for SO_2 and NO_x emission from ships, to be implemented by 2020 (IMO, 2008).

TSAP

The Thematic Strategy for Air Pollution (TSAP) scenario meets the health and environmental objectives, as proposed by the European Commission in its thematic strategy for 2020 (CEC, 2005). These objectives were achieved in this scenario in a cost-effective way, by reducing land-based emissions, without taking into account any further emission control measures for maritime shipping. The Dutch BGE emission scenario, in accordance with the RGE emission scenario, included all current measures and established policies. It also incorporated the proposals for national control measures, as presented in the Dutch National Air Quality Cooperation Programme (VROM, 2008a; VROM, 2008b), such as the national emission target for primary PM emissions in industry and the Dutch Energy and Climate action programme (VROM, 2008c; VROM, 2007).

EP

The European Parliament (EP) scenario aims at more ambitious health and environmental objectives for 2020 than those proposed by the Commission. Like in the TSAP scenario, further control measures for maritime shipping were not incorporated in this scenario.

The European Parliament noted in a resolution that the Thematic Strategy does not show how the objectives of the 6th Environment Action Programme (EC, 2002) can be attained, and called for the Commission to aim for a significantly higher level of ambition to reduce air pollution by 2020, in order tot achieve these objectives. In response to this resolution, IIASA developed an alternative set of environmental and health objectives. IIASA also estimated the cost-effective emission reductions needed to achieve these alternative objectives.

IMO

The so-called International Maritime Organization (IMO) scenario aims at the same health and environmental objectives as does the TSAP-scenario, with the distinction that the IMO scenario also takes into account additional control measures for international shipping. This scenario assumed the implementation of tighter controls for sea shipping (for details, see Amann *et al.*, 2008). Obviously, such extra emission reductions from international shipping alleviate some pressure for further reduction of land-based emission sources. The resulting set of cost-effective land based emission ceilings for countries for 2020 are generally less ambitious than for the TSAP case. The effect of this emission scenario on $PM_{2.5}$ levels may differ between countries, given the different contributions from international shipping to national $PM_{2.5}$ levels.

MRR

These are the Maximum emission Reductions considered in the RAINS/GAINS (MRR) scenario, which refers to the lowest level of emissions that can be achieved in various countries, through full application of the measures included in RAINS/ GAINS model (RAINS/GAINS model: see text box *Models* *for the assessment of particulate matter*). The RAINS/GAINS model does not consider non-technical measures, such as behavioural changes or structural changes (for example, fuel switching or additional savings in energy use). The effects on $PM_{2.5}$ in the Netherlands in relation to attainability of the exposure reduction target are shown in Chapter 6.

4 Approach

To research the attainability of $PM_{2.5}$ air quality standards in the Netherlands, models were used in combination with measurements. In this section, the approach is described for each $PM_{2.5}$ air quality standard, followed by the applied models. The section ends with a discussion on the uncertainty in the model results.

4.1 Approach per $PM_{2.5}$ standard

Exposure concentration obligation

Maps with $PM_{2.5}$ background concentrations for 2006, 2010, 2015 and 2020, calculated with the OPS model, were used to evaluate the attainability of the exposure concentration obligation (ECO). For more details on the OPS model and its application, see Section 4.2; also see Van Jaarsveld (2004) and Velders *et al.* (2009). The emissions used as input were in accordance with current and proposed Dutch and European policies (BGE/IMO see Table 3.1). The average exposure index (AEI) is the indicator to assess the ECO. In this assessment we used modelled concentrations of the twelve 1x1 km² grid cells that corresponded with the urban background locations (Figure 2.2). The assessment by MtB2007 used the average concentration of the six air quality agglomerations designated in the Netherlands as a proxy for the AEI. When we reapplied that approach, the calculated AEI values were similar and led to the same conclusion for the attainability of the ECO by 2015.

Standards for average annual $PM_{2.5}$ levels to be met at all locations

The OPS model in combination with the Luvotool model (see Section 4.2) were used to assess the attainability of the 25 µg/m³ level, as a limit value for 2015 and target value for 2010, as well as the 20 µg/m³ level (the Stage 2 indicative value to be met by 2020).

These standards concern the average annual $PM_{2.5}$ concentrations and should be met at all relevant locations, such as along busy streets. The highest $PM_{2.5}$ concentrations in the Netherlands are likely to be found mostly at traffic locations in urban agglomerations and along busy motorways. Therefore, current and future estimates of $PM_{2.5}$ concentrations at urban traffic locations and along motorways are believed to be the best indicators for assessing whether the aforementioned $PM_{2.5}$ standards will be attained in the Netherlands.

Model estimates for the contributions from local traffic at street level were calculated, separately, with the Luvotool model (PBL, 2008), for 2010, 2015 and 2020, and added to large-scale concentration levels calculated with the OPS model.

Exposure reduction target

Attainability of the exposure reduction target (ERT) was evaluated with the OPS model, but the emission input was prepared following a somewhat different approach. The effect of different recently issued emission scenarios relevant to the attainability of the ERT was examined with the GAINS-NL model (see Section 4.2). This approach was taken to link our assessment to the revision process of the EU Directive on National Emission Ceilings, where the RAINS/GAINS model was used for the assessment of the emission ceilings.

All emission scenarios (Section 3) yielded a concentration change of the AEI for 2020, compared to the Current Policy scenario AEI for 2010. To calculate the relative change, the AEI reductions were then divided by the AEI that resulted from the Current Policy scenario for 2010.

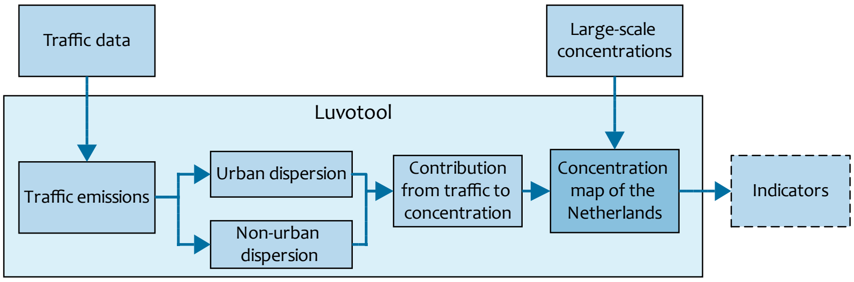
4.2 Models

OPS model

The Netherlands Environmental Assessment agency (PBL) uses the OPS model (Van Jaarsveld, 2004) to generate maps of average annual pollutant concentrations for the Netherlands, at 1x1 km² grid, for air quality components that are subject to European regulations (see text box *Methodology for calculating $PM_{2.5}$ concentrations*). These maps, in conjunction with more detailed calculations of contributions from local sources, are used to report on air quality, as obligated under the EU Air Quality Directive, as well as for impact assessments related to new spatial projects.

The OPS model provides a much higher resolution (1x1 km²) than, for instance, the EMEP model, which is used for describing the dispersion of air pollution for the GAINS model. The output domain of the OPS model, however, is limited to the air quality within the Netherlands (but takes sources within Europe into account). OPS model results were compared with EMEP results for $PM_{2.5}$ (see also Schaap *et al.* (2009), Cnossen and Velders (2009), and MtB2007).

Luvotool and its environment **Figure 4.1**



Calculation scheme in Luvotool, in this case for the indicator $PM_{2.5}$. Large-scale concentrations were calculated offline with the OPS model.

Luvotool: calculation of the contribution from local traffic sources

The contribution from local traffic sources on top of the large-scale $PM_{2.5}$ concentration was calculated with the Luvotool model (PBL, 2008). The model calculates a high resolution $PM_{2.5}$ concentration map (25x25 m² grid), as is shown in the calculation scheme in Figure 4.1. The model has two parts for calculating the contribution from traffic. For urban roads, the dispersion calculation is strongly parameterised using the CAR II model (Eerens *et al.*, 1993; Jonker and Teeuwisse, 2006). In the Netherlands, CAR II is widely used for assessing the contribution of air pollutants from street traffic. The model was updated in 2007 (Wesseling and Sauter, 2007). For non-urban roads, Luvotool assumes that a road section is a finite line source, and the distribution is calculated with a Gaussian plume model. The Luvotool calculations result in a map with contributions from local traffic for more than 8.2 million road segments of 25x25 m². This 'traffic' map is added to the large-scale $PM_{2.5}$ concentration map. Large-scale $PM_{2.5}$ concentrations calculated with the OPS model for 2010, 2015 and 2020, were based on Velders *et al.* (2009). The added traffic contributions were based on the $PM_{2.5}$ traffic emissions in accordance with the BGE scenario as described in Velders *et al.* (2009). In the combined $PM_{2.5}$ maps (large-scale + local traffic contribution), a correction was applied for motorways, otherwise a doubling would occur in the traffic contribution at those locations. In Section 5.1, *Standards for average annual $PM_{2.5}$ levels to be met at all locations,* statistics are shown for the three $PM_{2.5}$ concentration maps for 2010, 2015 and 2020, mentioned above.

GAINS-NL model

GAINS-NL is a RAINS/GAINS model version made available for national use. It focuses on the Netherlands (RAINS-NL and GAINS-NL; Aben *et al.*, 2005). GAINS-NL combines the emission generator of the GAINS model with a source receptor matrix based on OPS model results, to calculate, for instance, large-scale $PM_{2.5}$ concentration maps for the Netherlands on a 5x5 km² grid. The original RAINS/GAINS model has a much coarser resolution (50x50 km²). Input emissions are SO_2, NO_x, NH_3 and primary $PM_{2.5}$. The effect of VOC emission changes on $PM_{2.5}$ are not accounted for by the GAINS-NL model.

The RAINS/GAINS models are integrated assessment models that can be used to explore cost-effective emission control strategies to improve European air quality (RAINS) and, in addition, reduce emissions of greenhouse gases within Europe (GAINS) (Wagner *et al.*, 2006 and 2007). The RAINS/GAINS models use linearised relations between source emissions and concentrations, so-called source receptor matrices, which are calculated from EMEP model results. The GAINS model was used for the optimisation runs, forming the basis of the NEC-6 emission scenarios discussed in Chapter 3 (Amann *et al.*, 2008).

In this study, we used the GAINS-NL model in addition to the OPS model itself. Since OPS and GAINS-NL are based on the same model, the results are in close agreement. The AEI outcomes of OPS and GAINS-NL, with regard to the ERT evaluation, agree within about 7%. Such small differences are insignificant for the conclusions on the attainability of the ERT. The results from both model versions, therefore, were considered equal. Differences between the results of the two model versions were mainly caused by resolution differences (5x5 km² versus 1x1 km²), and by differences in the allocation of emissions to emitting sectors. Differences may also arise from model improvements which have been included in updated versions of the OPS model, but which have not yet been implemented in GAINS-NL.

EMEP model

The unified EMEP model (EMEP, 2003) is a chemical transport model for the European domain. Annual assessments for different air pollutants are derived from EMEP model calculations for the European domain and for each Member State (EMEP, 2007, 2008a and 2008b). The EMEP model, therefore, plays an important role in preparing policy for the European Union. $PM_{2.5}$ is part of the model output on a resolution of 50x50 km².

4.3 Uncertainties

This assessment faced major uncertainties in the measurements and model results. The $PM_{2.5}$ measurements carried out according to the reference method in 2008 had an uncertainty of about 20% (2 sigma). Modelled large-scale $PM_{2.5}$ concentrations were more uncertain: future $PM_{2.5}$ concentrations contained an uncertainty of 40% (2 sigma). Relative concentration changes based on model estimates between

2010 and 2020, to subsequently assess the attainability of the ERT, were even more uncertain. The calculated contribution from local traffic in streets and along motorways added yet another uncertainty. Vehicle emission factors for $PM_{2.5}$ were more uncertain than for PM_{10}. The extra uncertainty concerned the non-exhaust emissions of $PM_{2.5}$, which are due to tires, brakes and road wear.

Why is the uncertainty so large?

The large uncertainty is due to several factors:

- model limitations
- emission scenarios
- meteorological factors

The large uncertainty is inherent to modelling, and to the fact that particulate matter consists of contributions from many different sources, both anthropogenic and natural. The majority of the anthropogenic sources, relevant for $PM_{2.5}$, were included in our model, but some were not. For instance, VOC emissions that contribute to $PM_{2.5}$ through the formation of secondary organic aerosol were not included. The contribution from these sources and from natural sources was implicitly accounted for by calibration of the model results to measurements. For model estimates on the future, a constant add-on was estimated based on measurements and model calculations for historical years. The add-on represented the future contribution to $PM_{2.5}$ from natural and anthropogenic sources which were not accounted for by the model (see text box *Methodology for calculating $PM_{2.5}$ concentrations*).

Clearly, this approach introduced large uncertainties and likely a bias. A bias occurs when the model underestimates or overestimates the effect of emission changes. This is probably the case for the effect of VOC emission reductions, which would lead to a reduction in secondary organic aerosol, but SOA formation was not included in the model. In the IMO scenario, a reduction was foreseen of VOC emissions, between 2010 and 2020, of more than 30%, Europe wide (Table 3.2). Ambient levels of secondary organic aerosol in the Netherlands may be about 1 µg/m³. Model biases due to the leaving out of the effect of anthropogenic VOC emission changes on $PM_{2.5}$, are believed to have been smaller than 30% of that amount (< 0.3 µg/m³), since biogenic VOC emissions, which also contribute to secondary organic aerosol formation, would probably remain unchanged.

There are indications that secondary inorganic aerosol levels were also underestimated by the current model. Recent measurements performed within the BOP programme showed that our present model estimates and measurement series of ammonium nitrate and ammonium sulphate appeared to underestimate ambient levels by 30 to 40% (Weijers *et al.*, 2009). In that case, future emission reductions in the precursor gases SO_2, NO_x and NH_3, could more efficiently lower $PM_{2.5}$ than presented in this report.

Furthermore, the effects of the recent economic downturn were only partly represented by the emission scenarios studied in this report. Decreased economic activities generally

Methodology for calculating large-scale $PM_{2.5}$ concentrations

The methodology for calculating the large-scale concentration at any arbitrarily chosen location in the Netherlands can be divided into two steps. These are briefly described below.

Step 1. Calculating the background concentration. *This concerns the calculation of the concentration at rural and urban background locations with the OPS calculation model (Van Jaarsveld, 2004). This model includes source contributions from all of Europe. Primary and secondary (sulphate, nitrate, ammonium) fractions are calculated separately and then added together to obtain the total calculated particulate matter concentration. The secondary fraction consists mainly of fine particles. Based on literature and limited measurements, the model assumes that the following fractions of secondary particles are part of $PM_{2.5}$: 1.0 (ammonium), 0.9 (sulphate) and 0.8 (nitrate). The model results are sensitive to this approach, since about half of $PM_{2.5}$ consists of secondary inorganic aerosol. The secondary contribution to $PM_{2.5}$ from VOC (secondary organic aerosol) is still at the research phase and has not been included in the OPS model. The calculation resolution is 1×1 km². The inputs for the model include data on emissions, such as the strength of emissions and spatial and temporal distribution of the sources, both for the Netherlands and for other European countries. Meteorological data are also required. For calculations involving historical data, the model uses emission data for the Netherlands from the Netherlands Pollutant Release and Transfer Register (PRTR, 2009; Milieubalans, 2008) together with meteorological data for the relevant year. For calculations involving future years, the future emissions are estimated based on assumptions about developments of economic activities and emission factors, along with many-year average meteorological input (1995-2005). In the future projections, the effects of various emission scenarios are taken into account (see Chapter 3).*

Step 2. Calibration to measurements. *Calibration was required for $PM_{2.5}$, which was also the case for PM_{10}, because the model does not include all sources. Only about two thirds of the measured concentrations could be explained by the model. For 2008, the calculated $PM_{2.5}$ background concentrations were calibrated to the available measurements, while taking the uncertainties of the model and measurements into account. For 2008, a constant calibration value of 5.3 µg/m³ was found; this is the difference between the model results and the available $PM_{2.5}$ measurements in the Netherlands. This amount represented not only the contribution to $PM_{2.5}$ from sea salt, mineral dust, water, secondary organic aerosol and other sources, but also included the effect on other sources which may have been misrepresented by the model. The value of 5.3 µg/m³ is a rough estimate with an uncertainty of around 2.5 µg/m³. For future $PM_{2.5}$ concentration estimates, a calibration value of 6.1 µg/m³ was derived, based on a comparison between $PM_{2.5}$ and PM_{10} measurements and model results (see also Velders et al., 2009).*

lead to decreased emissions. Estimates of the effect of the economic recession on emissions in the Netherlands showed reductions with respect to the emission scenario used here for 2010 for SO_2 (7%), NO_x (8%), NH_3 (0%), NMVOC (8%) and primary PM_{10} (6%) (Koelemeijer *et al.,* 2009). At the same time all emission scenarios analysed in this report assume that EU Member States will comply with their national emission ceilings set for 2010. This assumption probably implies a decrease in emissions for several Member States as compared to their own emission projections for 2010. Altogether this may result in lower $PM_{2.5}$ concentrations for 2010 than presented in this analysis. However, meeting long-term goals for sustainable energy and energy savings appeared to be more difficult, because of diminishing investments in sustainable technology.

Finally, meteorological year-to-year fluctuations influence the attainability assessment of limit values for average annual $PM_{2.5}$ concentrations, but also play a role in the uncertainty with regard to the AEI and in assessing whether a concentration reduction can be significantly determined.

Distance to $PM_{2.5}$ targets

5

The results of our analysis on the distance to $PM_{2.5}$ targets are presented here for the Netherlands and were put in the context of the situation in the rest of the EU. The analysis was based on model results (Chapter 4) given the emission scenarios (Chapter 3) and available information on $PM_{2.5}$ concentration levels (Chapter 2). We evaluated the $PM_{2.5}$ limit values and target values, as well as the stage-2 indicative limit value of 20 µg/m³ (see Table 1).

5.1 Assessment for the Netherlands

Exposure concentration obligation

The exposure concentration obligation (ECO) is a limit value of 20 µg/m³ for the average exposure index to be met by 2015. Figure 5.1 shows the calculated levels for the average urban background concentration under current and proposed Dutch and European policies (BGE/IMO see Table 3.1)

In the case where only current Dutch and European policies are executed (RGE/CP), the AEI for 2015 was calculated to be 0.4 µg/m³ higher. The pink area in Figure 5.1 indicates the 13 to 18 µg/m³ range. If the AEI for 2010 is within this range, the exposure reduction target (ERT) is 15%, but when the AEI is higher than 18 to 22 µg/m³, the ERT is 20%.

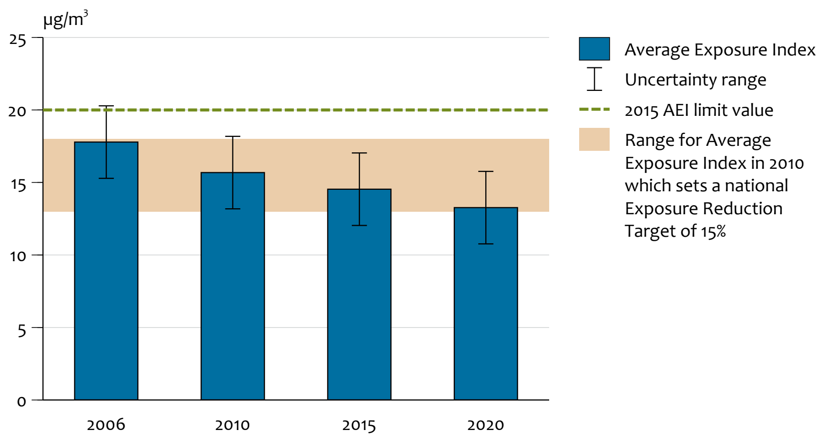
From the analysis based on current and proposed Dutch and European policies was concluded that:

- The ECO limit value of 20 µg/m³ is very likely to be met by 2015, even when only current Dutch and European policies are realised.
- Model results and measurements indicated that the AEI for 2010 probably will be less than 18 µg/m³. This conclusion is partly sustained by the current economic downturn. However, an AEI for 2010 of 18 µg/m³ or even higher, cannot be excluded. This resulted in an uncertainty about the national exposure reduction target, which may be either a 15 or 20% reduction in the AEI.

Standards for average annual $PM_{2.5}$ levels to be met at all locations

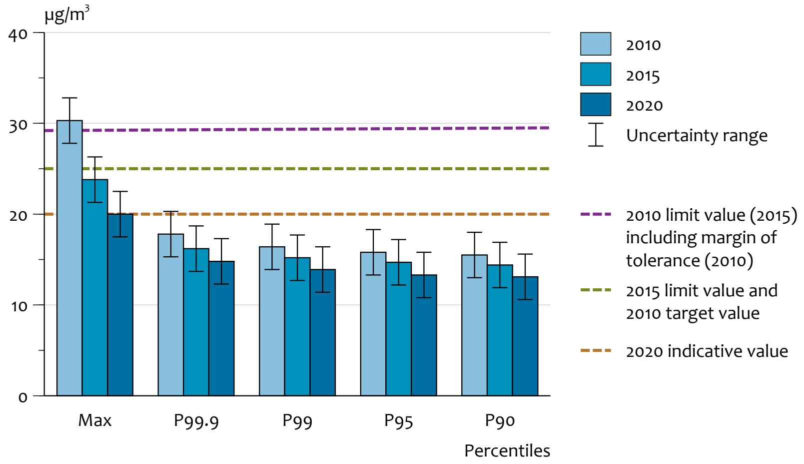
There are two $PM_{2.5}$ standards for average annual concentrations, to be met every year 'in each zone and agglomeration', in contrast to the ECO and ERT, which

Average Exposure Index $PM_{2.5}$ **Figure 5.1**



Average exposure index (AEI) calculated for 2006, 2010, 2015 and 2020, based on current and proposed Dutch and European policies (Velders et al., 2009), uncertainty: around 2.5 µg/m³.

Average annual $PM_{2.5}$ concentration with traffic contribution by percentiles **Figure 5.2**



Statistics of average annual PM2.5 concentrations for 2010, 2015 and 2020 in the Netherlands. Emissions are according to current and proposed Dutch and European policies (Velders et al., 2009; BGE/IMO scenario, Table 3.1).

concern three-year running average urban background concentrations.

- Limit value of 25 µg/m³ to be met by 2015*
- Target value of 25 µg/m³ to be met by 2010

*A margin of tolerance of 20% has been set, which started June 2008 and applies for all of 2009. Thereafter, the margin of tolerance decreases on the following 1 January and every 12 months by equal annual percentages, reaching 0 % by 1 January 2015. Consequently, this leads to the following limit results for the years 2009 to 2014: 30 µg/m³ (2009), 29.2 µg/m³ (2010), 28.3 µg/m³ (2011), 27.5 µg/m³ (2012), 26.7 µg/m³ (2013), 25.8 µg/m³ (2014). If these limits are exceeded, Member States must ensure that air quality plans are established for those zones and agglomerations, in order to achieve the relevant limit value.

The statistics in Figure 5.2 were based on more than 8.2 million grid cells of 25x25 m², where the $PM_{2.5}$ concentration levels were affected by local traffic emissions. Therefore, about 8200 grid cells of 25x25 m² had a concentration ranging between the maximum concentration (max) and the 99.9 percentile (P99.9). Statistics for high resolution $PM_{2.5}$ maps (25x25 m²) included the contribution from traffic for the relevant streets and motorways (Luvotool results; see Section 4.1).

The effect of meteorology

The model calculations used for this analysis were based on long-term average meteorology. However, the standards must be met every year, everywhere, also under unfavourable meteorological circumstances. The effect of such meteorological fluctuations was not included. Velders and Matthijsen (2009) showed that meteorological fluctuations can lead to variations of about 9% (1 sigma) in the annual PM_{10} concentration. Similar results are believed to hold for $PM_{2.5}$. In that case it is likely (probability> 66%) that $PM_{2.5}$ concentrations may exceed the concentrations shown in Figure 5.2, by 1 to 2 µg/m³ in the course of three years due to unfavourable meteorological circumstances.

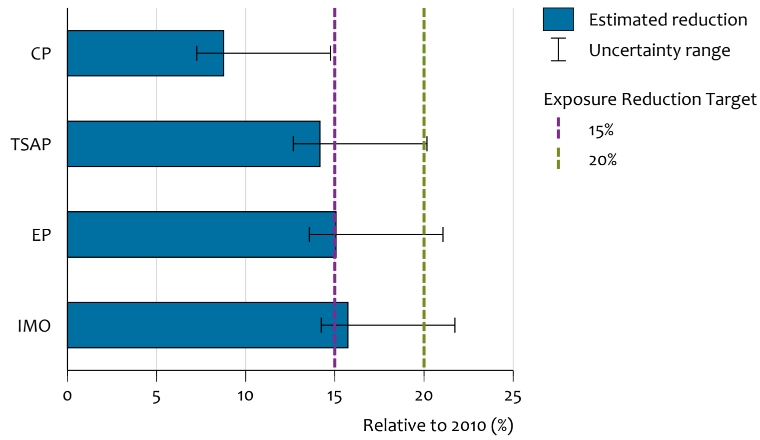
From the analysis based on current and proposed Dutch and European policies was concluded that:

- The $PM_{2.5}$ limit and target value of 25 µg/m³ will likely be met on time at most locations, probably also in years with unfavourable meteorological circumstances.
- The assessment for hot spots is most uncertain, because model uncertainty increases enormously when predicting extreme particulate matter situations. Based on the current study it appeared that
- in 2015 a very limited number of hot spots may occur along some motorways where the 25 µg/m³ limit value is exceeded under unfavourable meteorological circumstances.
- in 2010, when taking the margin of tolerance for that year into account, the resulting value of 29.2 µg/m³ may be exceeded at a limited number of locations. More exceedances will occur under unfavourable meteorological conditions.
- for average meteorological conditions, the $PM_{2.5}$ concentrations calculated for hot-spot traffic locations may be somewhat overestimated for 2010, partly due to the effect of the current economic recession, which was not included in our analysis. See also below, *The effect of the National Air Quality Cooperation Programme* (NSL).
- Attainability of the Stage 2 indicative limit value of 20 µg/m³ appears to be feasible by 2020.

The effect of the National Air Quality Cooperation Programme

In order to comply with the EU limit values for PM_{10} and NO_2, the Netherlands has formulated a National Air Quality Cooperation Programme (NSL: VROM, 2008a; VROM, 2008b). The programme contains a comprehensive package of measures at the local, regional and national scales to reduce air quality exceedances in the short term. Given the estimated effects of these measures, the European Commission decided in April 2009 to give the Netherlands more time to comply with the European air quality standards for PM_{10} (until mid-2011).

Reduction of Average Exposure Index per emission scenario, 2010 - 2020 **Figure 5.3**



AEI reductions between 2010 and 2020 relative to the AEI in 2010. The reductions result from the emission scenarios studied: CP, TSAP, IMO and EP (see Chapter 3). Table 5.1 shows the absolute AEI reductions between 2010 and 2020 calculated for these emission scenarios.

Absolute levels of reduction (μg/m³) between 2010 and 2020 calculated for the emission scenarios CP, TSAP, IMO and EP (see Chapter 3). **Table 5.1**

Scenario	AEI reduction (μg/m³), 2010 – 2020
CP	1.4
TSAP	2.3
EP	2.4
IMO	2.6

National generic measures, which are part of the NSL, were taken into account in our analysis. Local and regional measures, however, have not been accounted for. The effect of these local and regional measures, such as the implementation of environmental zones, on local $PM_{2.5}$ levels, is not well known. At present, about ten municipalities have introduced environmental zones for heavy-duty vehicles. Vehicle types of a certain age and older are banned from these zones. Brink (2009) showed the effect of environmental zones for passenger cars on PM_{10} and $PM_{2.5}$ concentration levels for different scenarios. He found insignificant effects on $PM_{2.5}$, in the short term (2010), of banning Euro1 cars and older. Banning Euro 3 cars and older was estimated to lead to an extra $PM_{2.5}$ reduction, locally, of about 1.3 μg/m³ in 2010. Generally, measures which reduce PM_{10} also affect the $PM_{2.5}$ concentration level. Therefore, the limited number of exceedances of the relevant $PM_{2.5}$ standards for 2010, 2015 and 2020 that may occur according to our analysis (see Figure 5.2) are expected to be even further reduced due to the local and regional measures of the National Air Quality Cooperation Programme.

Exposure reduction target

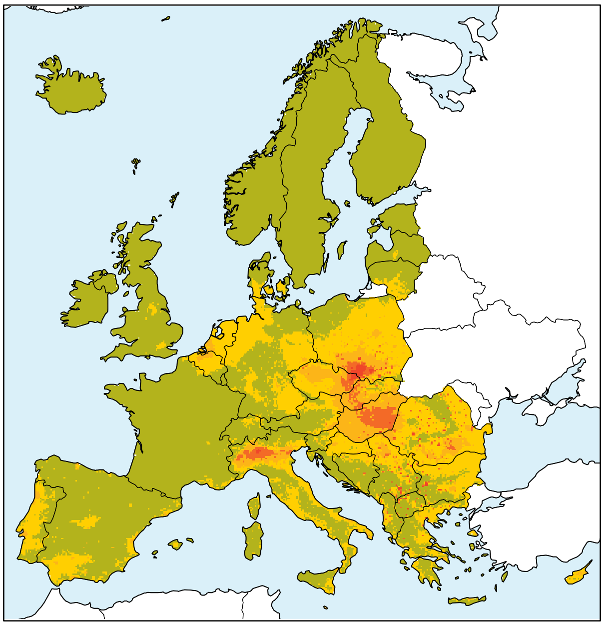
The average exposure index for 2010, which determines the ERT, is still unknown. From our model analysis – including uncertainties – it appears that AEI values of less than 18 μg/m³ may be expected for 2010. Nevertheless, a higher AEI value cannot be excluded. Therefore, exposure reduction targets of either 15 or 20% are currently being considered, although an ERT of 15% appears most likely. For 2010, we estimated an AEI value of about 17 μg/m³, based on current and proposed Dutch and European policies (IMO, Chapter 3). Figure 5.3 shows the results for the different emission scenarios (Chapter 3) with an ERT marked at 15 and 20%.

Note that the IMO scenario favours larger $PM_{2.5}$ reductions in the Netherlands than the EP scenario. The efficient reduction of $PM_{2.5}$ in the Netherlands resulting from reduced shipping emissions in the IMO scenario is caused by the proximity of very busy shipping corridors on the North Sea.

It can be concluded from our model estimates that:

- An ERT of 20% is not attainable for the Netherlands with technical emission reduction measures, except when additional measures are taken, Europe wide (for instance, MRR emission scenario, see next chapter). The other emission scenarios yielded reductions of the AEI between about 9 and 16%.
- An ERT of 15% is probably attainable for the Netherlands given the foreseen emission policies (IMO and EP emission scenarios). Other emission scenarios, CP and TSAP, failed to meet an exposure reduction target of 15%. However, in case of the TSAP emission scenario, 15% reduction is within the uncertainty limits.
- There are large uncertainties concerning the present estimates of the AEI reduction between 2010 and 2020. The uncertainties indicate that AEI reductions are probably larger (by 1 μg/m³ or more) than the current estimates. This

Estimated average annual $PM_{2.5}$ concentration, 2005 **Figure 5.4**



Map of estimated average annual $PM_{2.5}$ concentrations in Europe, 2005. The map was derived from scaled rural and urban PM_{10} maps using region-specific $PM_{2.5}$ to PM_{10} ratios (Horalek et al., 2008). The figure was adapted from De Leeuw and Horalek (2009).

would mean that AEI reductions of even 20% are within the uncertainty margin (see also Section 4.3).

5.2 Assessment for other EU countries

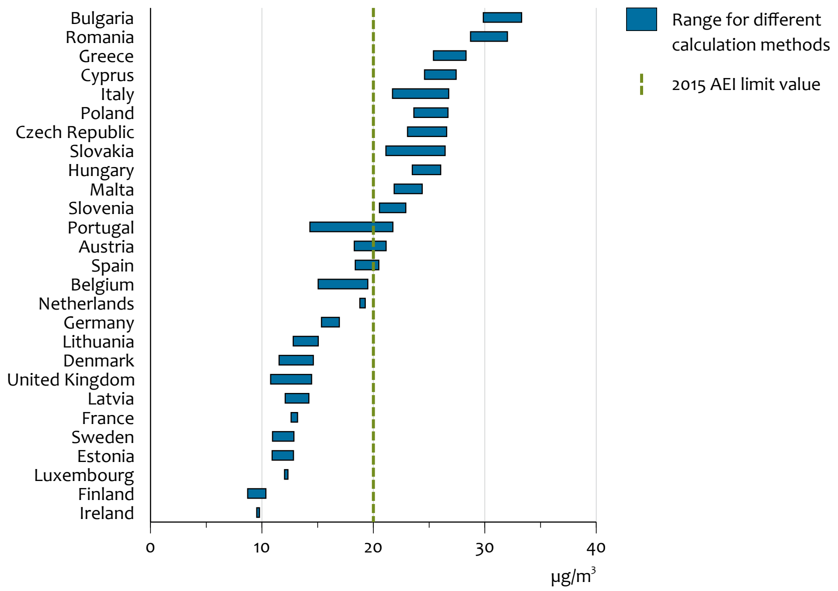
The available $PM_{2.5}$ measurements for Europe (see Figure 2.4) indicate that several EU countries will face more serious problems than the Netherlands in attaining the target and limit value of 25 µg/m³ on time. In some Member States, measured $PM_{2.5}$ concentration levels are well above 30 µg/m³ (see also Section 2.2.). The European policies, which focus on reducing pollutant emissions from vehicle engines, will lead to lower $PM_{2.5}$ concentrations at all traffic locations, Europe wide. However, the traffic-related contribution to $PM_{2.5}$ from non-exhaust emissions and re-suspension remains, and these components vary in magnitude throughout Europe. We did not have the data on aspects such as local traffic to assess attainability in more detail for other Member States regarding the target and limit value of 25 µg/m³.

Meeting the exposure concentration obligation by the deadline may be difficult for several Member States without measures that go beyond the European ambitions. Furthermore, it is unclear whether Member States will face problems meeting their national exposure reduction target value, for two reasons:
- The national ERT levels of the individual countries are still unknown.
- The level of implementation of technical and non-technical reduction measures differs throughout Europe.

We estimated the variability of the $PM_{2.5}$ levels, Europe wide, which are inferred from PM_{10} measurements reported to the EEA air quality database (AirBase, 2008) by following the approach reported in De Leeuw and Horalek (2009). This approach takes advantage of the abundance of PM_{10} measurements, the fact that PM_{10} includes the fine fraction and the spatial statistics on the $PM_{2.5}$ to PM_{10} ratio. For this purpose, $PM_{2.5}$ to PM_{10} ratios were derived from a selected set of collocated AirBase measurements (see Table 2.1).

We used the $PM_{2.5}$ maps to evaluate the AEI-based $PM_{2.5}$ standards: ECO and ERT. The AEI was calculated as the concentration in the urban grid cells weighted according to the population in that cell. Figure 5.5 shows calculated AEI values for 2005 in the 27 EU Member States. The range pictured per Member State can be seen as the sensitivity of the AEI value for the different approaches that are used to calculate the AEI (for details, see De Leeuw and Horalek, 2009). It turned out that the AEI in eleven Member States in 2005 was well above the obligation for 2015 – irrespective of the calculation method. In three Member States, the AEI was, depending on the calculation method, just below or above the level of 20 µg/m³. In the other twelve Member States, the AEI was estimated to be well below the binding limit value of 20 µg/m³. The AEI estimate for the Netherlands was between 18 and 19 µg/m³, which was in line with the observed urban background concentrations (see Figure 2.1).

Average Exposure Index $PM_{2.5}$, 2005 — Figure 5.5



Average exposure index calculated for 2005 using European, region-specific and country-specific concentration ratios. The range in the figure was caused by the different approaches used to calculate the AEI. The figure is adapted from De Leeuw and Horalek (2009).

6

Additional measures and the ERT

The emission scenarios, of which results are shown in Chapter 5, are currently being debated. The emission scenario used for the Netherlands is linked to current and proposed Dutch policies (IMO in Figure 5.3). European legislation on future $PM_{2.5}$ concentrations is currently being formulated (e.g. Energy and Climate package, revision of both the National Emission Ceiling Directive and the Gothenburg protocol). Regarding their effects on emissions, the outcome of these processes is uncertain. To support national policy decision-making on these processes, the effect of additional measures on the attainability of the exposure reduction target is shown below. We addressed the effects of additional national measures separately from the effects of additional Europe-wide measures. (see Table 6.1).

6.1 Additional national measures

We explored two scenarios with additional national measures to investigate how the Netherlands can achieve AEI reductions between 2010 and 2020 that are larger than those found for the IMO scenario (see Figure 5.3). We used the IMO scenario, which includes current and proposed Dutch policies (BGE), as the reference. We applied the same approach as for the ERT assessment in Chapter 5. The additional national measures are the AGE scenario and the MRR-NL scenario.

AGE

The AGE scenario shows the results of the national strategy on possible additional measures on top of current and proposed policies. Emissions outside the Netherlands are unchanged with respect to the IMO emission scenario. The AGE scenario projects the following reductions in 2020, in addition to the national BGE scenario: for primary $PM_{2.5,}$ only 2 tonnes (for road transport), for NO_x, 36 kilotonnes (mostly from tightening the ETS standard for power plants and industry), for SO_2, 4 kilotonnes, (for industry, mostly steel) and for NH_3, no further reductions are envisaged. For more detail, see Velders *et al.* (2009).

MRR-NL

The MRR-NL scenario shows the results of the GAINS strategy on maximum emission reductions in the Netherlands. Emissions outside the Netherlands are unchanged with respect to the IMO emission scenario. The MRR-NL emission reductions in 2020 with respect to the national emissions (BGE) in the IMO scenario are as follows: for primary $PM_{2.5}$, 1.7 kilotonnes, for NO_x,17 kilotonnes, for SO_2, 5 kilotonnes and for NH_3, 11 kilotonnes.

6.2 Additional local measures

The National Air Quality Cooperation Programme (NSL: VROM, 2008a; VROM, 2008b) contains, amongst other aspects, measures to achieve local reductions of exceedances of the limit values for PM_{10} and $NO_{2,}$ in the short term. These measures could affect local $PM_{2.5}$ concentrations, but they were not taken into account in this analysis. Their effect on the AEI reduction between 2010 and 2020 is, however, expected to be insignificant.

Measures on a local scale, such as regulations that reduce the traffic volume locally, or placement of screens that alter the

Overview of emission scenarios used for the evaluation of additional national and Europe-wide measures — **Table 6.1**

Emission scenario	Year	Netherlands	Rest of Europe[2]	International Shipping
IMO	2020	BGE[1]	TSAP – after international shipping measures	IMO[3]
AGE	2020	AGE[1]	As above	IMO
MRR-NL	2020	Maximum Reductions[2]	As above	IMO
MRR	2020	Maximum Reductions[2]	Maximum Reductions	IMO

1) according to Velders *et al.*, 2009
2) according to Amann *et al.*, 2008
3) according to IMO, 2008.

Overview of emission scenarios used for the evaluation of additional national and Europe-wide measures on the reduction of $PM_{2.5}$ concentrations between 2010 and 2020.

Emission totals (kilotonnes) for the Netherlands as part of the emission scenarios IMO, AGE and MRR-NL. The MRR-NL national emissions are according to Amann *et al.*, 2008. **Table 6.2**

	IMO[1)]	AGE[2)]	MRR-NL[3)]
$PM_{2.5}$	13.6	13.6	11.9
NO_x	198	162	181
SO_2	47	43	42
NH_3	129	129	118

1) BGE national emission scenario, Velders *et al.*, 2009;
2) AGE national emission scenario, Velders *et al.*, 2009;
3) based on national RGE emission for 2020, reduced with the emission difference between the CP and the MRR emission scenarios, according to the GAINS model for 2020. See also Annex A.

local air circulation, can help to attain a limit value at specific hot spots. However, only regulations that lead to reduced emissions can help attain the exposure reduction target, which aims at a reduction of average urban background concentrations. A transition to cleaner forms of transport, such as electric driving, will have an impact on $PM_{2.5}$ concentrations on all scales.

Zero exhaust emissions for road traffic

Nagelhout and Ros (2009) evaluated the transition to electric driving. For electric and/or hydrogen powered vehicles, exhaust emissions are reduced to zero. If all road traffic in the Netherlands were to have zero exhaust emissions by 2030, $PM_{2.5}$ concentrations would decline, on average, by about 0.6 µg/m³, nationwide. Along motorways and busy streets, reductions would be larger (1.5 - 3 µg/m³). These reductions are relatively small compared to the effect of the European emission standards for vehicles over the period from 1990 to 2030. In addition, emissions due to brakes, tires and road wear would not be affected by the transition to zero exhaust emissions. The extra concentration reduction would be limited, but it concerns a health-relevant PM fraction. Furthermore, exposure to the exhaust fraction would be considerably larger than when the same energy would be generated by power plants with high smokestacks. In addition, emissions that result from fuel production would decrease (e.g. from refineries). The decrease would be partly counteracted by an emission increase in the electricity sector. The net effect of electrical or hydrogen-powered vehicles would be an improvement of urban air quality.

6.3 Additional measures, Europe wide

We explored one scenario with additional measures on a European scale: the MRR scenario. This emission scenario assumes an all out application of technical reduction measures included in the RAINS/GAINS database.

MRR

A vast range of emission scenarios is possible with various measures in other Member States that go beyond the present European ambitions. Here we have illustrated only a possible upper-limit effect on $PM_{2.5}$ concentrations by applying the MRR scenario, Europe wide (see also Chapter 3). The MRR emission scenario includes many measures from different sectors. In 2020, these measures would lead to important additional emission reductions relative to the IMO scenario (see Table 3.2): $PM_{2.5}$ (-38%), NO_x (-16%), SO_2 (-35%), NH_3 (-25%) and VOC (-32%). See Amann *et al.* (2008) for more details.

6.4 Effect of additional measures

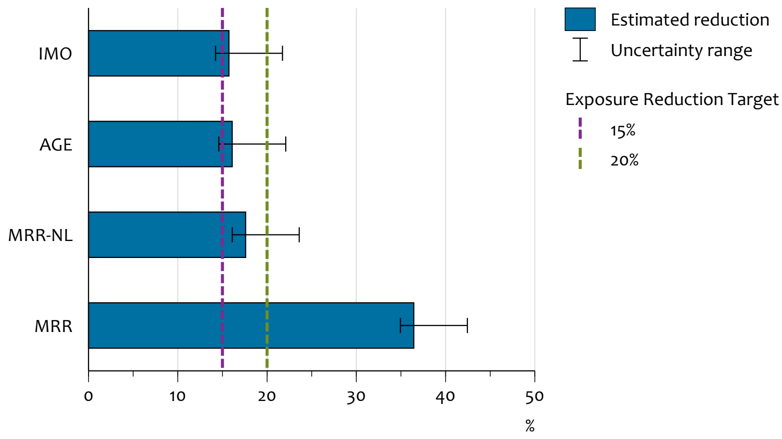
The effect of additional measures, taken in the Netherlands, on the reduction of the AEI is limited (Figure 6.1). In 2020, the AGE scenario would lead to an additional AEI reduction of about 0.05 µg/m³, relative to the national IMO scenario. In 2020, the MRR-NL scenario would lead to an AEI reduction of about 0.3 µg/m³, relative to the IMO scenario. When emission reductions for SO_2, NO_x, NH_3 and primary $PM_{2.5}$ are applied Europe wide, according the MRR scenario, we calculated a reduction of 3.4 µg/m³ additional to the 2.6 µg/m³ reduction calculated for the IMO scenario.

Note that the MRR-NL emission scenario is not totally consistent with the national emission scenarios. Consequently, emission reductions foreseen in the MRR-NL scenario may be smaller or larger than when the all-out application of possible technical measures are used for establishing national emission estimates.

The following was concluded from our model estimates on the effects of additional measures on the attainability of the ERT in the Netherlands:

- Additional national measures have a limited effect on the attainability of the ERT in the Netherlands.
- AGE scenario: no significant additional AEI reduction relative to the IMO scenario.
- MRR-NL scenario: AEI reduction improves by 2% (from 16% under the IMO scenario to 18% under MRR-NL).
- If maximum emission reductions would be applied Europe wide (MRR), the upper limit AEI reduction was calculated at 36%.

Reduction of Average Exposure Index with additional measures, 2010 - 2020 — Figure 6.1



Relative reductions of the AEI between 2010 and 2020, due to the following emissions scenarios: IMO with different national emissions scenarios: current and proposed policies (BGE), additional policies (AGE), and maximum emission reduction according to RAINS (MRR-NL). The MRR scenario with maximum emission reductions, Europe wide, would result in an upper limit effect.

Absolute levels of reduction (µg/m³) between 2010 and 2020 calculated for the emission scenarios IMO, AGE, MRR-NL and MRR — Table 6.3

Scenario	AEI reduction (µg/m³), 2010 – 2020
IMO	2.6
AGE	2.6
MRR-NL	2.9
20%	3.2
MRR	5.9

7

Conclusions

This report provides an analysis of the attainability of $PM_{2.5}$ air quality standards, which are part of the new EU Air Quality Directive (EU, 2008b). The findings reported in an earlier assessment have been updated with new information on measurements, models and emissions. Based on our findings, we came to the following conclusions on the main question: Can the $PM_{2.5}$ air quality standards set for $PM_{2.5}$ be met in the Netherlands?

- All limit values and target values for $PM_{2.5}$ appear to be met on time under current and proposed national and European policies to improve air quality. However, a very limited number of exceedances of the 25 μg/m³ target value may occur in 2010. Even when taking the margin of tolerance for that year into account, the resulting value of 29.2 μg/m³ may be exceeded at a very limited number of traffic locations.
- The $PM_{2.5}$ standards appear not to be more stringent than the current PM_{10} limit values. This situation might change when the EU air quality directive will be revised in 2013.
- Current and proposed policies which aim to abate PM_{10} also help to reduce $PM_{2.5}$, especially those policies that mainly reduce the emission of fine particles, such as combustion aerosol.
- Meteorological fluctuations may cause additional exceedances, possibly also of the 25 μg/m³ limit value in 2015.
- The exposure concentration obligation (ECO) will very likely be met in 2015 without supplemental policy (current national and European policies only).
- The exposure reduction target appears to be the most stringent $PM_{2.5}$ standard for the Netherlands. There is still uncertainty about the national ERT level (either 15 or 20%). However, an ERT level of 15% is most probable. The current model estimates showed that 15% is attainable, but 20% is not, unless many more measures that go beyond present European ambitions are taken, both on national and European scales. Additional national measures are insufficient by themselves.
- An ERT of 15% appears to be measurable in the Netherlands. It is theoretically possible to measure an AEI reduction of 12% (95% confidence limits) with statistical significance, given the current $PM_{2.5}$ measurement setup in the Netherlands, the average annual $PM_{2.5}$ concentrations with a measurement uncertainty of 20% and a standard deviation of 18% due to year-to-year meteorological fluctuations.
- A number of Member States will probably face problems attaining the $PM_{2.5}$ standards. The challenge of meeting the $PM_{2.5}$ standards, on time, appears to be difficult especially for Member States in eastern Europe, given the present concentration levels and the European ambition on emission reductions. This concerns meeting the $PM_{2.5}$ limit values, as well as the target values.
- Meeting the Stage 2 indicative value of 20 μg/m³ by 2020 appears to be possible in the Netherlands, under current and proposed national and European policies.

The underlying assessment is uncertain because of the unfinished state of legislation in Europe; this legislation will influence future $PM_{2.5}$ concentrations (e.g. revision of the National Emission Ceiling Directive and the Gothenburg protocol).

Our analysis was limited by large uncertainties in the models and measurements, especially with regard to the ERT assessment. On the one hand, our model estimates are believed to underestimate rather than overestimate the effect of anthropogenic emission reductions on future $PM_{2.5}$ concentrations. This means that larger relative reductions, resulting from current and proposed national and European policies – even up to 20% – are within the margin of uncertainty. Furthermore, concentrations at hot-spot traffic locations may be somewhat overestimated for 2010, partly due to the effect of the current economic recession, which was not included in our analysis. On the other hand, $PM_{2.5}$ concentrations levels and the trend are not well understood, in terms of sources and dispersion; consequently, more pessimistic developments cannot be excluded either, at this point. Finally, all emission scenarios analysed in this report assume that EU Member States will meet their emission goals for 2010. The current economic downturn will probably cause this assumption to become reality. However, it may prove to be somewhat optimistic to assume that the newly drafted emission ceilings for 2020 will be met in time by all EU Member States.

Annex A National $PM_{2.5}$ emissions per sector

National projections for 2010, 2015 and 2020, of primary $PM_{2.5}$ emissions (kilotonnes) per sector for the Netherlands **Table A1.1**

	GE, Global Economy			Measures additional to the current policy scenario, RGE (kilotonnes)	BGE	AGE
	RGE	BGE	AGE			
***2010*[1]**						
Industry	3.8	3.8	3.8			
Refineries	0,4	0.4	0.4			
Energy	0.3	0.3	0.3			
Waste	0.1	0.1	0.1			
Transport	7.4	7.4	7.4	Stimulating Euro 6 standards (diesel cars) from 2009		< 0.1
Agriculture	1.8	1.8	1.8	Measures on poultry housing facilities at PM exceedances	pm	
Consumers	3.3	3.3	3.3			
TSG[4]	0.6	0.6	0.6			
Sea Shipping	8.0	8.0	8.0			
Total[3]	17.6	17.6	17.6			
2015						
Industry	4.0	3.4	3.4	PM reduction plan in food, chemical and primary metal industries	0.6	
Refineries	0.4	0.4	0.4			
Energy	0.6	0.6	0.6			
Waste	0.1	0.1	0.1			
Transport	5.1	5.0	5.0	Road pricing from 2011/12; Effects of Euro 6 standards (diesel cars) from 2009; Euro VI standards (heavy transport) from 2012	0.1	< 0.1
Agriculture	1.8	1.8	1.8	Measures on poultry housing facilities at PM exceedances	pm	
Consumers	3.2	3.2	3.2			
TSG[4]	0.7	0.7	0.7			
Sea Shipping	8.5	8.5	8.5			
Total[3]	15.9	15.2	15.2			
2020						
Industry	4.3	3.0	3.0	PM reduction plan in food, chemical and primary metal industries	1.3	
Refineries	0.5	0.5	0.5			
Energy	0.7	0.7	0.7			
Waste	0.1	0.1	0.1			
Transport	3.9	3.7	3.7	Road pricing from 2011/12; Stimulating Euro 6-standards (diesel cars) from 2009; Euro VI-standards (heavy-duty vehicles) from 2012	0.2	
Agriculture	1.8	1.8	1.8	Measures on poultry housing facilities at PM exceedances	pm	
Consumers	3.2	3.2	3.2			
TSG[4]	0.7	0.7	0.7			
Sea Shipping	9.0	9.0	9.0			
Total[3]	15.1	13.6[2]	13.6[2]			

1 Consequences of the current recession have not yet been processed for 2010. Economic development follows the interpolation between 2006 rate and the 2020 projections. Actual 2010 emissions are expected to be lower.
2 Emission ceiling for 2020, according to TSAP ambition (IIASA, 2008) = 16 kilotonnes.
3 Total of NEC categories, excluding Sea Shipping.
4 TSG: Trade, Services and Government.

National projections for 2010, 2015 and 2020, of primary $PM_{2.5}$ emissions (kilotonnes) per sector for the Netherlands, calculated on the basis of PM_{10} emissions and estimates of the ratio $PM_{2.5}$–PM_{10}. See also Velders et al. (2009).

Projections for 2020 of national emissions per sector for primary $PM_{2.5}$, NO_x, SO_2 and NH_3 (kilotonnes) for the Netherlands

Table A1.2

	$PM_{2.5}$	NO_x	SO_2	NH_3
2020[1]				
Industry	2.4	21.0	14.0	2.6
Refineries	0.2	5.3	16.0	0.1
Energy	0.4	30.2	11.5	0.5
Waste	0	3.7	0.3	0.4
Transport	3.9	96.9	0.4	2.7
Agriculture	1.6	9.7	0	103.5
Consumers	2.8	7.8	0.1	8.0
TSG[4]	0.6	6.3	0.1	0.6
Total[3]	11.9	181	42	118

3 Total of NEC categories, excluding Sea Shipping.
4 TSG: Trade, Services and Government.

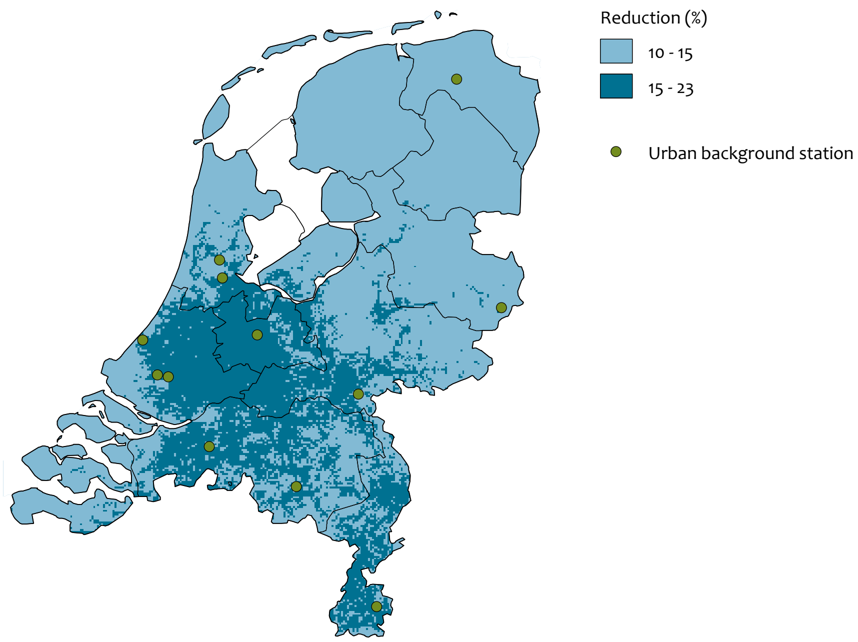
Projections for 2020 of national emissions per sector for primary $PM_{2.5}$, NO_x, SO_2 and NH_3 (kilotonnes) for the Netherlands. The emissions are based on the national RGE scenario reduced with the difference between the CP and MRR emission scenarios for the Netherlands (Amann et al., 2008). The MRR scenario affects stationary sources only.

MRR-NL

The effect on $PM_{2.5}$ of measures in addition to current and proposed national emission policies is discussed in Chapter 6. For all components besides NO_x, the MRR-NL emission scenario is the most ambitious of the three scenarios explored. Table A1.2 shows the MRR-NL emissions for 2020 per sector and per component for the Netherlands. The emissions for the Netherlands generated by the GAINS model deviate from the national emission estimates, because the GAINS model has not yet included updated information on national emission projections. In order to keep to a single approach, the MRR-NL is based on national emission estimates adapted by applying the changes per sector between the CP and MRR emission scenario for the Netherlands, according to the GAINS model.

Annex B Spatial distribution of $PM_{2.5}$ reduction

Reduction $PM_{2.5}$ concentration, 2010 - 2020 **Figure B1.1**



Calculated $PM_{2.5}$ reduction in the Netherlands between 2010 and 2020, calculated for the BGE national emissions scenario, and the IMO scenario for the other European countries. This emission scenario contains the current and proposed national and European policies, according to Velders et al. (2009), the so-called GCN-2009 emission scenario. The dots signify the location of the $PM_{2.5}$ urban background stations, as in Figure 2.2.

Glossary

AEI
Average Exposure Index

AGE
National emission scenario, as BGE but including additional outlined national control measures

BGE
National emission scenario, as RGE but including proposals for national control measures

Airbase
Air Quality Database of the European Environment Agency

BOP
Netherlands Policy oriented Research Programme on PM_{10} and $PM_{2.5}$

CAR II
Calculation of Air pollution from Road traffic

CP
Current Policies

DCMR
the Rotterdam Environmental Protection Agency

ECN
Energy research Centre of the Netherlands

ECO
Exposure Concentrations Obligation

EC/OC
Elemental Carbon / Organic Carbon

EEA
European Environment Agency

EMEP
European Monitoring and Evaluation Programme

EP
European Parliament emission scenario

ERT
Exposure Reduction Target

GAINS
Greenhouse Gas and Air Pollution Interactions and Synergies model

GGD
Public Health Service

IIASA
International Institute for Applied Systems Analysis

IMO
International Maritime Organization emission scenario

LML
Netherlands Air Quality Monitoring Network

Luvotool
Model for the contribution from traffic to air pollution

MRR
Maximum emission Reductions scenario considered in the RAINS/GAINS model

MtB2007
Refers to Matthijsen and Ten Brink (2007)

NEC
National Emission Ceiling

NH_3
Ammonia

NMVOC
Non-Methane Volatile Organic Compounds

NO_x
Nitrogen oxides

NSL
National Air Quality Cooperation Programme

NTA
Netherlands Technical Agreement

OPS
Operational Priority Substances model

PBL
Netherlands Environmental Assessment Agency

PM
Particulate Matter

PM_{10}
Concentration of particles less than 10 microns in diameter

$PM_{2.5}$
Concentration of particles less than 2.5 microns in diameter

RAINS
Regional Air Pollution Information and Simulation model

RGE
National emission scenario Global Economy, current and established policies

RIVM
National Institute for Public Health and the Environment

SO_2
Sulphur dioxide

TNO
Netherlands Organisation for Applied Scientific Research

TSAP
Thematic Strategy on Air Pollution

VOC
Volatile Organic Compounds

VROM

Dutch Ministry of Housing, Spatial

Planning and the Environment

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In 2008, the European Directive on air quality established air quality standards for fine particulate matter ($PM_{2.5}$). Presently, the Netherlands is in the process of adapting its policy, monitoring methods and models to comply with the requirements for $PM_{2.5}$. To support this process, this report provides an assessment of the attainability of the various air quality standards for $PM_{2.5}$. It is likely that all limit and target values for $PM_{2.5}$ will be met in time under current and proposed national and European policies, assuming average meteorological conditions. Therefore, the $PM_{2.5}$ standards appear not to be more stringent than the current PM_{10} limit values. This situation might change when the EU air quality directive will be revised in 2013. Uncertainties in this assessment are large. Therefore, it cannot be ruled out that a very limited number of exceedances of the 25 µg/m^3 target value may occur along busy streets, by 2010. Meteorological fluctuations may cause additional exceedances, possibly also of the 25 µg/m^3 limit value, by 2015. The exposure reduction target (ERT) is a target to reduce the average national $PM_{2.5}$ concentration at urban background locations, between 2010 and 2020. The ERT value for the Netherlands has not yet been set; 15% being the most probable. On a theoretical basis, it appears that an ERT of 15% can be measured with enough significance given the studied $PM_{2.5}$ monitoring set up.

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PO Box 303, 3720 AH Bilthoven, The Netherlands