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ANALYSIS OF FACTORS INFLUENCING THE DEVELOPMENT OF GREENHOUSE GAS, NO_X AND SO_2 EMISSIONS IN THE EUROPEAN UNION.

BACKGROUND DOCUMENT TO "OUTSTANDING ENVIRONMENTAL ISSUES IN THE EUROPEAN UNION IN 2004"

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by order of the:
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1 Introduction

In the second half of 2004 the Netherlands will hold the presidency of the European Union. One of the agenda items during the presidency will be strengthening of the 'environmental pillar' of the so-called Lisbon Strategy. The Ministry of Spatial Planning and the Environment initiated several projects to supports this strategy. One of these projects is a report by the National Institute for Public Health and the Environment (RIVM) on "Outstanding Environmental Issues". This report will focus on opportunities and threats to solve persistent environmental problems in Europe. The target group for the report are the new European Commission, new Members of the European Parliament and policy makers in EU Member States.

The RIVM has asked Ecofys to support them with this report by making a qualitative analysis of:

- Factors influencing the development of emissions of greenhouse gases (Total GHGs and CO_2 in particular), NO_x and SO_2 emissions in the industry sector (see chapter 2)
- The effect of diffent policies on the level of greenhouse gas emissions (see chapter 3).

2 Factors influencing emissions of GHG, NO_x and SO_2 in industry

2.1 Introduction

The industry sector includes all manufacturing activities ranging from the production of steel, aluminium, cement and bulk chemicals to the manufacturing of all kinds of equipment. We have not included industries that convert primary to final energy (electricity production sector, production of refined products, cokes and nuclear products); these fall under the energy industries. Main outstanding environmental issues for industry include the emissions of greenhouse gases, SO_2 and NO_x. The bulk of these emissions are linked to the use of energy. Sectors primarily responsible for the emissions of these pollutants are therefore the energy intensive industry sectors such as steel production, production of chemicals and cement production. Figure 1 (see annex 1) shows the added value and final energy use per industrial subsector in the EU-15, in 2001. Figure 2, Figure 3 and Figure 4 provide an overview of the developments in value added, energy consumption and the emissions of CO_2, NO_x and SO_2 in the period 1996-2020 for the EU-25, EU-15 and the member states that entered the European Union in 2004. The figures show that there is a decoupling between value added of the industry and emissions of these pollutants.

2.2 Policies and targets

Table 1 provides an overview of European Policies aimed at reducing the emission of CO_2, NO_x and SO_2 in industry.

Table 1 Overview of major European Policies and Objectives specifically aimed at the industry sector.

Description of policy (year)	Objective(s), target(s) and measures included	Target group
Emissions Trading Directive (2003/87/EC) (EC, 2003a) The Directive creates a market for CO_2-emission allowances. Every installation covered by the scheme must apply for a permit, or the right to emit	The objective is to promote reductions of CO_2 in a cost-effective and economically efficient manner. The penalty for non-compliance (a shortage of allowances by the end of the year) is 40 euro per ton in the first three-year period and	Electricity and heat production; Mineral oil refineries and coke ovens; Iron and steel and metal industries; Glass, pottery and building materials (including cement);

Description of policy (year)	Objective(s), target(s) and measures included	Target group
CO_2. Member States need to set a maximum limit on the amount of emissions from industrial installations. When the installation exceeds that limit, it will have to buy allowances from other installations that have excess allowances. There is a pilot phase in the years 2005-2007 and a definite introduction of the system in 2008-2012.	100 euro per ton in the later period.	Paper and printing (including paper pulping).
Large Combustions Plant (LCP) Directive (2001/80/EC) (EC, 2001a) Directive on the limitation of emissions of certain acidifying pollutants to the air from large combustion plants. The forerunner of the directive was already in place in 1988. The Directive also encourages the combined generation of heat and power and sets specific emission limit values for installations that use biomass as a fuel.	Aims to reduce emissions of NO_x, SO_2, fine particles by setting minimum standards for these substances for different types of power plants and fuel types. Member States are obliged to draw up appropriate programmes for the progressive reduction of total annual emissions from existing plants, and must take appropriate measures to ensure that all licences for new plants contain conditions concerning emission limit values	Industrial combustion plants with a rated thermal input equal to or greater than 50 MW, irrespective of the type of fuel used (solid, liquid or gaseous)
IPPC Directive: Integrated Pollution Prevention and Control including the adaptation for F-gases (1996/61/EC) (EC,1996) (EC,2002) The IPPC Directive holds a set of common rules for specific industrial installations (e.g. combustion installations for >50 MW_{th}, production installation ferrous metals, chemicals) and was published in 1996. These specific installations are required to obtain an authorisation (permit) from the authorities in the EU countries. Unless they have a permit, they are not allowed to operate. The permits must be based on the concept of Best Available Techniques (or BAT).	In essence, the IPPC Directive is about minimising pollution from various point sources throughout the European Union.	Industry
National Emission Ceilings (NECs) Directive (2001/81/EC) (EC, 2001b) This Directive sets upper limits for	The emissions ceilings are designed to meet objectives for acidification, eutrophication and ground-level ozone pollu-	Industry (whole sector), Energy production, Transport, Agriculture

Description of policy (year)	Objective(s), target(s) and measures included	Target group
each Member State for the total emissions in 2010 of the four pollutants responsible for acidification, eutrophication and ground-level ozone pollution (SO_2, NOx, VOCs and ammonia), but leaves it largely to the Member States to decide which measures to take in order to comply.	tion against the lowest costs possible	
European Energy Tax Directive (EC,1995) (EC, 2003b) The tax agreement defines harmonised minimum tax rates for energy products. Under current EU law only mineral oils are subject to minimum tax rates. The newly agreed draft directive will extend this framework to include coal, natural gas and electricity while raising existing minimum rates for oil products.	Objectives of introducing an energy tax are to increase the costs for energy consumption in order to create an incentive for energy savings. There are already energy taxes in the UK, Denmark, Germany, Finland, France and the Netherlands. Almost all tax levels in northern European countries are already higher than the ones now agreed upon. Some tax levels in southern European countries and new Member States will need to be increased.	Industry (whole sector) and other sectors

European policies aimed at increasing energy efficiency and reducing greenhouse gas emissions (listed above) are of recent date and have not yet affected CO_2 emissions in the last decade. National policies aimed at improving energy efficiency and/or reducing CO_2-emissions mainly include voluntary agreements (there are e.g. negotiated agreement on energy efficiency improvement in Denmark, Germany, the Netherlands, Sweden and the United Kingdom) and financial incentives like fiscal measures and grant schemes (almost all Member States have some form of financial incentives in place).

In most EU Member States national policies to reduce the emissions of NO_x and SO_2 in the last decade included setting maximum emission standards for different types of installations and types of fuel used. In the last few years some countries have introduced (or are planning to introduce) trading systems for NO_x and/or SO_2 in order to lower costs for further reductions. The Netherlands plans to introduce a NO_x trading systems this year and Poland is planning to introduce a NO_x and SO_2 trading system.

2.3 Approach

2.3.1 Aim

Aim of this study is to analyse the effect of different developments on the emissions of CO_2, SO_2 and NO_x in the manufacturing industry in the past and in the future. It concerns developments in economic activity, industrial structure, energy intensity and fuel consumption.

2.3.2 Scope

The industry sector analysed includes all manufacturing activities, industries that convert primary to final energy (electricity production sector, production of refined products, cokes and nuclear products) are not included; these fall under the energy industries. For the purpose of the analysis the manufacturing industry is divided in the sub-sectors: iron and steel, chemical, non-metallic mineral products, paper and printing and other industry. These sub-sectors have a considerable contribution in the final energy use of the overall sector (see Figure 1 in annex 1).

Emissions analysed are the emissions of CO_2, SO_2 and NO_x related to the final energy consumption and process related emissions. This means that we analysed changes in the emissions, which are attributed to the industry sectors in the international emission inventory (hence, UNFCCC Common Reporting Format (CRF) categories 1A2 and 2). This means that we did not analyse changes in emissions due to changes in purchased electricity and heat consumption of the sector.

2.3.3 Methodology

The method used to analyse the effect of different developments is the decomposition method used in several RIVM Environmental Balances (RIVM, various years), which is extensively described in Harmelink et al (1995). A comparable method to analyse energy end-use trends and changes in energy-related emissions was used by the IEA (OECD/IEA, 2004). The decomposition method can be used to analyse the impact of the following developments on emission levels:

- *Structural changes*. These changes result from a shift in activity level between different sub-sectors within industry. When activity levels e.g. shift toward less energy intensive sectors this results in a lowering of energy-related emissions.
- *Fuel mix changes*. These changes result from a shift in the type of fuels used to cover the final energy demand of the industry sector. In the analysis a distinction is made for primary fuels between coal, oil, natural gas. Because these primary fuels have different emission factors (emissions per unit of energy) changes in the type of fuels used results in changes in emissions level. Emissions from final energy in the form of heat and electricity are not considered here.

- *Changes in energy intensities*. This is related to changes in energy use per unit of value added. Energy intensity can improve (i.e. decrease) because of the implementation of energy saving measures, hence a clear benefit for the environment. However, it can also decrease because of changes in the product mix within a specific sub-sector. Changes in the product mix can result in a higher added value of a sub-sector while the amount of energy is being consumed is growing less than value-added. In the latter case, energy intensity is decreasing, but energy use is increasing.
- *Changes in process emissions*. These are changes in the emissions of greenhouse gases (CO_2 as well as non-CO_2 greenhouse gases), NO_x and SO_2 resulting from specific (non-energy related) production processes. Changes result from altering the production process, changes in raw material input and application of end-of pipe measures.

The following equation forms the basis of the analysis:

$E = A * (\sum_j(S_j * I_j * F)+P)$

In this decomposition

E	represents total emissions of the industry sector
A	represents overall sectoral activity, i.e. value-added in the manufacturing industry
S_j	represents the sectoral structure, i.e. shares of value-added by manufacturing sub-sector j
I_j	represents the energy-intensity of each sub-sector j, i.e. energy use per value-added sub-sector j
F	represents emissions related to final fuel mix within the sector, i.e. emission per unit of energy use in manufacturing industry
P	represents process emissions per unit of value added

First step in the analysis is the definition of the reference scenario. This is the hypothetical scenario in which no changes takes place in industry structure, fuel mix, energy intensity and process emissions as of 1990. This means that emissions in the reference scenario develop parallel to the activity indicator (value added). All other components remained fixed at reference year values. Subsequently to determine the effects of the other indicators each time another additional indicator is set free. Finally resulting in an overview of the actual emissions by varying all indicators.

The decomposition approach is illustrated by the different curves in the graphics (see e.g. Figure 5 in annex 1). The lower curve represents the actual emissions in industry, including the effects of changes in structure, fuel mix, energy intensities and process related emissions. The upper curve represents the hypothetical emission that would have occurred if no changes had taken place. The other curves give insight in the effect of separate factors and or measures.

In this decomposition method the effects of different developments are determined in a fixed order in which roughly first the impact of autonomous developments, secondly the impact of general policies and thirdly the impact environmental policies is determined. This means that first structural changes, secondly changes in the fuel mix, thirdly changes in energy intensity and finally the changes in process related emissions are calculated. By applying this method the absolute effects of changes are mutually dependent and the additional effect of each step is dependent on the absolute effect of the preceding step. It is not always obvious that developments are either autonomous, triggered by general policies or specific environmental policies. In these cases another order in which the effect of developments is determined can be applied. This is e.g. the case for changes in fuel mix and changes in energy intensity, which are partly autonomous triggered by general energy policies and by specific environmental policies. A sensitivity analysis however showed that the results do not change significantly when the order of changes in fuel mix and changes in energy intensity are changes.

2.4 Data sources

The NewCronos Database (Eurostat, 2004) is the main source for the historical data of energy consumption, added value, producer price indices and steel production. The trends for 2020 are based on annual growth rates from NTUA (2003). Data on emissions to air of GHGs, NO_x and SO_2 are taken from EEA (2003). In general more detailed information is available for the EU-15 countries than for the New Member States. For the New Member States we were only able to include 7 instead of 10 of the New member States, as data for the Czech Republic, Cyprus and Malta were not available. The results for the EU-15 also relate to another period then for the new member states (EU-15 from 1990, new member states as from 1996). In addition there is less detailed information available for SO_2 and NO_x than for CO_2 emissions. For NO_x and SO_2 no data are available on the sub-sector level and the impact of changes in structure and energy intensity on emissions can therefore not be shown separately.

2.5 Greenhouse gas emissions

2.5.1 Historical emissions

Figure 5 and Figure 6 provide an overview of industrial greenhouse gas emissions and CO_2-emissions in the **EU-15** countries including an analysis of the developments responsible for the observed changes in emissions between 1990-2001. The greenhouse gas emissions are dominated by the emission of CO_2 (86% of the total greenhouse gas emissions of the industry in 2001), followed by the emission of N_2O and F-gasses both 7% in 2001. Figure 5 in annex 1 shows that without changes in fuel mix, industry structure, energy intensity and applied technology the greenhouse gas emissions in the EU-15 would have increased with 16% over the last decade. The actual emissions have decreased with 12% in the period 1990-2001. These reductions largely result from one-off reductions in Germany due to the closure of inefficient industrial plants in former Eastern Germany.

Changes in emission were caused by the following developments:

- The reduction in CO_2 emissions due to structural changes is relatively small. An important contribution to this reduction is the lower share of the energy-intensive iron and steel industry in overall value-added of the manufacturing industry. This share changed from approximately 2.2% in 1990 to approximately 1.6% in 2001.
- Changes in fuel mix led to a considerable reduction in CO_2 emission. In the period 1990 – 2001 a shift from solid fuels and oil products towards gas products occurred within the industrial sector. The share of solid fuels decreased from 21% in 1990 to 12% in 2001, while the share of gas products increased from 33% to 39% in the same period.
- Another important reduction in CO_2 emissions is due to a decline in sectoral energy intensities. CO_2 emissions declined due to an improvement of the energy intensity of the chemical industry and the non-metallic-mineral products, despite an increase of the energy intensity of the steel and iron industry (As already mentioned before changes in energy intensity are the combined changes in energy efficiency and changes in the product mix. Looking in more detail into the steel sector for example shows that energy efficiency of the steel industry improved as energy intensity increased (see Figure 13)[1].

It must be noted that about half of the reduction due to structural changes, changes in fuel mix and changes in energy intensities took place in Germany.

Applied reduction options

It is difficult to say which specific measures are responsible for the energy savings realised within the industry sector during the last decade. In the period 1990 – 2001 several technologies were introduced which have a large impact on reducing energy consumption and/or which can be considered as breakthrough technologies. An important energy conservation option in the iron and steel industry has been the application of continuous casting. In 1998 the penetration of continuous casting was about 83% worldwide. In European countries this penetration is even higher (for instance 99% in Austria, Denmark, Italy and Portugal). Thin slab casting is the suc-

[1] This could indicate that the energy efficiency is outweighed by a shift to more energy intensive and/or lower value added products. However this conclusion is uncertain, because it is unknown how reliable the data are and it looks if not all price effects are left out account.

cessor of continuous casting and also a important (coming) technology. Scrap pre-heating and other innovations are leading to highly efficient Electric Arc Furnaces (EAFs). In the chemical industry process integration and intensification are applied more often. In addition membrane technologies are gradually becoming more widely applied. Pre-calciner kilns/horizontal roller mills and increased waste burning are important energy conservation options in the cement industry. In the glass industry oxygen-fired furnaces and cullet preheating, and in the bricks and ceramics industry, roller kilns and short tunnel kilns are important energy saving measures (Worrel, 2004).

- Apart from the greenhouse gas emissions related to the use of fossil fuels, process-related CO_2 and N_2O emissions have declined as well. The process related CO_2 emissions are dominated by the cement industry. The emission decrease mainly resulted from the switch to less carbon intensive raw materials. The N_2O emissions are mainly resulting from the production of adipic acid and nitric acid. Emission of N_2O have been reduced by 50% in the period 1990-2001 mainly due to the implementation of end-of pipe technologies by the manufacturers of adipic acid.

Results of our analysis are in line with the results found by the IEA (IEA/OECD, 2004):
- A shift from oil to gas products is for a considerable part responsible for the CO_2 emission reduction realised.
- The impact of energy intensity changes on CO_2 emission reduction is about 2.5 as high as structural changes.

Figure 7 and Figure 8 in annex 1 presents the greenhouse gas emissions and the CO_2-emissions in industry in the 7 **New Member States** (Czech Republic, Cyprus and Malta are not included). Greenhouse gas emissions are dominated by CO_2 emissions (88 %). Greenhouse gas emissions in these New Member States have declined in the period 1990-2001[2] by almost 20%. This decrease in emission is mainly due to the closures of inefficient industry plants in the beginning of the '90. Changes in industry structure and energy intensity are therefore the most important drivers for this decline in greenhouse gas emissions. Like the EU-15 a shift from solid fuels towards gas products can be observed in the New Member States. The share of solid fuels decreased from 38% in 1996 to 31% in 2001 and the share of gas products increased from 25% in 1996 to 30% in 2001. The process related emissions of CO_2 and N_2O increased in the period 1996 – 2001. This means that no substantial measures were taken within the cement and chemical industry (nitric and adipic acid production). The process related emissions of F-gases are not available for the New Member States.

[2] Data on emission are available for the period 1990-2001, but because data on value added are only available as of 1996 the figures only represent the period 1996-2001.

2.5.2 Trend to 2020

Figure 3 shows that the CO_2-emissions are expected to decline until 2005 and will then stabilize until 2020. It is expected that changes in industry structure, fuel mix and sectoral energy intensities lead to a decrease in CO_2-emission until 2005. The overall emissions in the industry in the **EU-15** will however stabilize as of 2005 because growth in production levels of the industry outweighs developments leading to lower CO_2-emissions. The relative reduction due to structural changes is caused by a decrease of the share of energy-intensive industries, such as the iron and steel and the non-metallic mineral industries. From 2001 up to 2020 a further shift from oil products and solid fuels towards gas products is expected. However the effect of this shift is much less prominent then observed in the period 1990-2001. Improvement of the sectoral energy intensities delivers the most important contribution towards limitation of CO_2 emissions in industry.

Figure 4 shows that the decline in CO_2-emissions in the New Member States that started in the early '90 will continue up to 2020. Energy use of the industry is expected to decline until 2020.

It must be noted that the introduction of the CO_2-emission trading system for the EU-25 is not yet included in the projections until 2020. The Member States are currently still in the process of preparing the National Allocation plans. First indications however show that allocation of CO_2-right to the industry will not lead to reductions beyond business as usual developments (CO2 newsletter, 2004).

2.5.3 Reduction options in the future

Based on a bottom up analysis, the potential in 2010 for CO_2 emission reductions in the industrial sector is estimated to be around 22% compared to the frozen technology reference level in 2010 (Ecofys, 2001). In this analysis only emission reduction options are considered that have a high probability of being commercially available before 2010. Over 90% of the potential can be attained at costs below 20 euro per tonne of CO_2-equivalent.

Some technologies that may have an important contribution to reducing the overall environmental impacts are summarised in Table 2 (Ecofys, 2002).

Table 2 Important emission reduction options in industrial sub-sectors

Sub-sector	**Measures**
Iron and steel industry	Smelt reduction technology Strip casting/spray casting techniques
Plastics	Membrane reactors Gas turbine integration in steam crackers Catalysts for new and existing polymers

Sub-sector	Measures
Cement/concrete	Techniques to reduce CO_2 emissions in the production process by using alternative raw materials Chemical recycling of concrete High-strengths cements/geopolymeric cements
Paper and printing industry	Material gasification for fuels Improved pressing and drying concepts
Aluminium	Non-consumable anodes and wettable cathodes

2.6 SO_2 emissions

2.6.1 Historical emissions

Figure 9 in annex 1 provides an overview of the SO_2 emissions in industry in the **EU-15** including an analysis of the factors responsible for changes in these emissions. Figure 9 in annex 1 shows that without changes in fuel mix, industry structure, energy intensity and other technical reduction measures the emission would have increase with 16% over the period 1990-2001. Actual SO_2 emissions in the EU-15 were reduced with 60% in the last decade, as a result of the following developments:

- The effects of structural changes and improvements on energy intensities on SO_2 emissions are relatively small compared to the effect of changes in fuel mix, the application of end-off pipe technologies and changes in the input of fuels and raw materials.
- The main reduction of SO_2 emissions has been achieved by changes in fuel mix, changes in the fuels used and the application of end-of-pipe-measures. The shift from oil and coal (both resulting in SO_2-emissions) toward natural gas (with zero SO_2-emissions) resulted among others from the European policies on the liberalisation of energy markets and the security of energy supply. Another important measure is the reduction of the sulphur-content in the oil and coal products used in the industry. In the period 1990-2001 SO_2-reduction mainly resulted from the implementation of national policies, which was later on supported and enforced by European Directives: the Large Combustion Plant Directive (and its forerunners) and the NEC directive. These Directives forced Member States to set emission standards for SO_2.
- Changes in process related emissions contribute considerably to the overall reduction of SO_2 emission of the EU-15 industry during the period 1990-2001. Chemical industry is mainly responsible for these emissions. Measures that have been applied are e.g. desulphurisation of raw material and/or use of raw material with a low sulphur-content. Reductions mainly result from national policies. European policies like the IPPC Directive only came in place in 1996 and large results cannot be expected yet, because Member States had three

years time to fully implement the Directive. Also in future years no large effects are expected from the IPPC Directive, because the directive is not very strict and leaves a lot of room for interpretation on the Member State level.

Figure 10 in annex 1 gives an overview of the development of SO_2 emission in industry in 7 **New Member States**, including the impact of changes in industry structure and energy intensities, fuel mix and end-of-pipe measures in the period 1996 – 2001. In this period SO_2 emissions declined with 35%. In the period 1990-2001 emissions have decrease with over 70%. This reduction is mainly due to structural changes in the industry sector and improvement of the sectoral energy intensity, because of the closure of inefficient plants in the beginning of the '90. Also changes in fuel mix (more gas and less solid fuels), process related emissions and end-of-pipe measures contributed favourably towards a reduction in SO_2 emission of the industry.

2.6.2 Trend to 2020

Projections are that with current policies in place SO_2-emission in the EU-15 as well as the new Member States will decline in the period 2001-2020 with about 1% –1.5% per year compared to 5% in the period 1990-2001 (IIASA, 2004). Part of the further reductions are coming from the shift toward natural gas, which is however less prominent than in the period 1990-2001 (see figure Figure 3 and Figure 4).

2.7 NO_x-emissions

2.7.1 Historical emissions

Figure 11 in annex 1 provides and overview of the NO_x emissions in industry in the **EU-15** including an analysis of the developments responsible for changes in these emissions. Figure 11 shows that without changes in fuel mix, industry structure, energy intensity and other technical reduction measures the emission would have increase with about 16%. The following developments led to reductions in NO_x-emissions, resulting in total reduction of the NO_x emissions in the EU-15 with 21% in the last decade.

- The effects of structural changes and improvements on energy intensities on NOx emissions are relatively small compared to the effect of changes in fuel mix, the application of end-off pipe technologies and changes in the input of fuels and raw materials.
- The reduction in NO_x emissions due to change in fuel mix and end-pipe measures are somewhat larger than the reduction due to decline in energy intensities. Technical measures include measures like low-NOx burners and flue gas recirculation. In the period 1990-2001 NO_x reduction mainly resulted from the im-

plementation of national policies, which was supported and enforced by European Directives: the Large Combustion Plant Directive (and its forerunners) and the NEC directive. These Directives forced Member States to set emission standards for NO_x.

- The decrease in process emissions of NO_x per unit of value added was relatively small and was mainly due to measure taken in the chemical industry. Reductions mainly result from national policies. As with SO_2 reductions European policies like the IPCC Directive only came in place in 1996 and large results cannot be expected in the analysed period.

Figure 12 in annex 1 shows the NO_x emissions in industry in 7 **New Member States** over the period 1996-2001. Mainly due to changes in industry structure and sectoral energy intensities NO_x emissions declined considerably during these 5 years (about 17%). In addition changes in fuel mix, process related emissions and end-of-pipe measures have a positive contribution to the reduction.

2.7.2 Trend to 2020

Figure 3 and Figure 4 show that with current policies in place NO_x-emission in the EU-15 as well as in the New Member states will stabilise (or increase slightly) until 2020 (IIASA, 2004).

2.8 Smart European Policies

In order reach further reductions of greenhouse gases, NO_x and SO_2 policies on the national and European level need to be strengthened. Options to strengthening European policies are:

- Tightening of CO_2 emission caps and extensions of the European Emission Trading Systems to other sectors and greenhouse gases. The Emission Trading Systems planning to start at the beginning of 2005 will probably not yet lead to large reductions. Tighter emission caps, extension of the systems to other sectors and including emissions of the non-CO2 greenhouse gases provides ample opportunities to reach deeper reductions.
- European covenants for technology development in the heavy industry. In order to reach deeper reductions of greenhouse gases innovation are required in production technologies. A European covenant with manufacturers from energy intensive industries could be effective in the development of innovative technologies.
- Introduce a European Motor Drive programme. Electricity consumption of the industry is currently not covered under the emissions trading systems. About 70% of the electricity consumption of the industry is consumed by motor drive system, and is indirectly responsible for about 40% of the CO_2, NO_x and SO_2 emission with the electricity production sector. There is a huge potential to reduce electricity consumption of motor drive systems but

because of lack of knowledge and reluctance with manufacturers reduction options are often not implemented. A European Motor Drive programme including amongst others quantitative targets could stimulate the implementation of this reduction potential.

2.9 Conclusions: main messages

- Industrial greenhouse gas emissions are still dominated by the emissions of the EU-15 that contribute to 85% of the greenhouse emissions, while 15% of the emission coming from the New Member States.
- Industrial greenhouse gas emissions in the EU-15 have decreased by 12% since 1990, despite a growth in added value of 16%. The reductions mainly result from one-off reductions in Germany due to the closure of inefficient industrial plants in former Eastern Germany.
- In the New Member states greenhouse gas emissions have decrease with 20% over the period 1990-2001. This decrease in emission is mainly due to the closures of inefficient industry plants in the beginning of the ’90. Changes in industry structure and energy intensity are therefore the most important drivers for this decline in greenhouse gas emissions.
- Decoupling of greenhouse gas emissions in the EU-15 and the New Member States in the period 1990-2001 mainly resulted from the shift from coal and oil to natural gas and an improvement of the energy intensity. In the EU-15 there is also a decrease in process related greenhouse gas emission with the cement and chemical industry. It must be noted that changes in energy intensity are not just resulting from improvement in energy efficiency but are also due to changes in the product mix of the industry.
- The shift from coal and oil to natural gas resulted amongst others from the introduction of European policies aimed at the liberalisation of energy markets and the security of energy supply. Liberalisation led to more competition on the energy markets and has led to a relatively more competitive situation for gas compared to solid fuels.
- Contribution of European policies on improvement of energy efficiency is very limited and is not expected to increase substantially in the near future under the European Emission Trading scheme because first indications show that allocation of CO_2-right to the industry will not lead to reductions beyond business as usual developments.
- CO_2 emission of EU-15 industry are expected to decline until 2005 and will stabilize in the period until 2020. In the period after 2005 reductions through the shift towards the use of more natural gas is limited and improvements in energy efficiency will not be enough to offset growth of industry production to result in an absolute decrease in CO2-emissions. CO_2-emissions in the new member states are however expected to decline further until 2020.

- Industrial emission of SO_2 and NO_x have drastically decreased, by 63% and 35%, respectively in the period 1990-2001, mainly because of application of end-of-pipe techniques and changes in the fuel mix in the EU-15, and because of the closure of old energy-intensive plants in the new member states. With current policy in place, future industrial SO_2 and NO_x emissions are projected to decrease further.
- In the period 1990-2001 NO_x and SO_2 reduction mainly resulted from the implementation of national policies, which were supported and enforced by European Directives: the Large Combustion Plant Directive (and its forerunners) and the NEC directive.
- A wealth of technologies exists or can become available to mitigate emissions of CO_2. The technical emission reduction potential of all greenhouse gases in 2010 is estimated to be about 26% compared to the frozen technology level in the same year. Over 90% of this potential can be attained at costs below 20 euro per tonne of CO_2-equivalent.
- In order to continue a further reduction of the emission of CO_2, NO_x and SO_2 strengthened of policies is need e.g. through:
  - Tightening of CO_2 emission caps and extensions of the European Emission Trading Systems to other sectors and greenhouse gases.
  - European covenants for technology development in the heavy industry in order to stimulate the development of innovative technologies aimed at deep reduction in the period 2020/2030.
  - Introduction of a European Motor Drive programme to stimulate electricity savings in the industry.

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3 Policies affecting GHG emissions

3.1 Introduction

This chapter analyses the effect of different policies on development in greenhouse gas emissions. Figure 14 (appendix 2) provides the result of this analysis in graphical form. The figure provides an overview of the developments in greenhouse gas emissions in the EU-15 in the period 1990-2001 and an estimate of the level of greenhouse gas emissions in the absence of different types of policies.

Greenhouse gas emissions in the EU-15 more or less stayed on the same level in the period 1990-2001 (EEA, 2003). It is estimated that in the absence of policies in the period 1990-2001 greenhouse gas emission would have been 4.7% higher in 2001. Policies described in the following paragraph contributed to a stabilization of the greenhouse gas emissions.

3.2 Renewable energy policies

Under the influence of renewable energy policies on the EU and the Member State level renewable electricity production increased with almost 10% per year, and renewable heat production with 2% per year (EC, 2002; IEA, 2003). Assuming that in the absence of renewable energy policies the electricity and the heat would have been produced with fossil fuels the greenhouse emission in the EU-15 would have been 1.5% higher in 2001 (IEA, 2003)[3].

Under the influence of the Directive on Renewable Electricity and the Directive on biofuels Member States (EU-15 and new Member States) will be forced to strengthen their policies in the field of renewable energy. Expectations are that renewable energy production will further increase, resulting in a relative decrease in CO_2-emissions.

[3] Assumption: Electricity would otherwise have been produced with a natural gas fired power plant with an efficiency of 50% and heat is otherwise produced with a natural gas fired boiler with an efficiency of 90%.

3.3 Landfill gas policies

Under the influence of waste policies emissions of methane from landfill sites have decreased with 25% over the period 1990-2001[4]. On the EU level the Landfill Directive was introduced requiring among others greater use of landfill gas collection and energy recovery from the produced methane. Assuming that in the absence of landfill gas policies CH_4 emissions per ton of waste would have stayed on the same level as in 1990 the greenhouse emission would have been almost 1% higher in 2001 (EC, 2004).

Landfill policies have not reach their full potential yet, and New Members States just started with the implementation of measures to collect landfill gas. This means that the emissions will go further down.

3.4 BAT technologies adipic acid production

N_2O emissions within the industry have decreased with more than 50% in the period 1990-2001. Most N_2O emissions from chemical industries occur in the adipic and nitric acid production. Most of the reductions were achieved between 1997 and 1999 due to the implementation of reduction measures in the German, French and UK adipic acid production (EEA, 2004). Measures to reduce N_2O emissions were included in national regulation for the industry because the techniques were considered BATNEEC (Best Available Technologies Not Exceeding Costs) (NOP, 2001)[5]. Assuming that in the absence of policies N_2O emissions per ton of adipic acid would have stayed on the same level since 1990 the greenhouse emission would have been almost 1% higher in 2001.

Further reduction of N_2O from the industry will mainly have to come from the implementation of measures with the nitric acid production. Different technologies to reduce these N_2O emissions are currently developed and tested. It seems likely that one of the technologies will be ready for deployment before 2010.

[4] The municipal waste amount is reduced by 0.2% per year. The implemented measures at landfill sites lead to an improvement of the emission factor (kg CH4/kg waste) of 2.5% per year.

[5] As stated the largest effect is due to taken measures in the adipic acid industry: 73% N_2O emission reduction during the period 1990-2001. The adipic acid production itself decreased only slightly with 1% in the same period. The nitric acid production decreased considerably with 15% between 1990 and 2001. In addition due to implemented measures the emission factor within the nitric acid industry (kg N_2O/kg nitric acid production) decreased with 3% during the same period.

3.5 Cogeneration (CHP) policies

There has been a considerable increase in the amount of installed cogeneration capacity (mainly natural gas) in the EU-15: the amount of electricity produced with cogeneration plants increased with 5% per year in the period 1990-2001 and the amount of heat produced with 2 % per year during the same period (IEA, 2003). CHP was promoted with different types of national policies like subsidies, fiscal measures and feed-in tariffs. Without additional CHP greenhouse gas emission would have been 0.4 % higher in 2001 (IEA, 2003)[6].

In 2004 the European Parliament accepted the Directive on Cogeneration. The directive is aimed at increasing the amount of installed high efficiency CHP in the European Union. As the directive does not hold quantitative targets it is hard to tell what the effect will be on a further increase of CHP.

3.6 Efficiency improvements in the build environment

The energy consumption for space heating per household decreases in the nineties (Eurostat, 2003)[7]. National policies promoted thermal insulation and energy efficient heating systems through building standards and financial incentives. The autonomous development is assumed to be 1% per year. Without additional energy savings through policies in the build environment the greenhouse gas emissions would have been about 1% higher in 2001.

In 2003 the Directive on the Energy Performance of Buildings (EPBD) was accepted. The directive sets the framework for development of energy efficiency requirements for new and existing buildings on the Member State level. Expectations are that due to this directive energy efficiency improvements in the build environment will increase.

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[6] Assumptions: All additional produced energy from cogeneration plants since 1991 is taken into account. Mainly new gas fired capacity was installed. As references was used electricity produced with a natural gas fired power plant with an efficiency of 50% and heat produced with a natural gas fired boiler with an efficiency of 90%.

[7] The general trend is a decline of energy consumption for space heating per household in several North Western European countries (in EU-15 about 2.5% per year). However note that the estimated energy consumption for space heating varies considerably per year, due to uncertaincies in available data (for instance share of space heating). The number of households increased with 0.9% per year. The estimated energy consumption for space heating decreased with 1% per year. The corresponding CO_2 emission decreased more with 1.6% per year due to the switch of used fuels for space heating (from coal and oil products to gas).

3.7 Common Agricultural Policies (CAP)

European Common Agricultural Policies were not specially aimed at the reduction of greenhouse gases. However as a side effect of polices aimed at reducing the amount of nitrate in groundwater emissions of N_2O decreased slightly[8]. A further side effect of these policies is a reduction of the livestock leading to a reduction of CH_4 emissions. In the absence of CAP the emissions of greenhouse gases would have been 0.3% higher[9].

3.8 Sensitivity analysis

The effect, in terms of CO_2-eq attributed to the different policies, is sensible to assumptions with respect to the reference case. The results are especially affected by assumptions regarding the reference case for electricity production. In the analysis in this chapter we assumed that electricity produced by means of renewable energy sources or CHP would otherwise have been produced with a natural gas fired power plant with an efficiency of 50%. There are good arguments for this choice. New electricity production capacity installed over the last ten years was mainly natural gas fired, so additional renewable and CHP is replacing this natural gas fired capacity. However one can also argue that the contribution of renewables and CHP is so small that is does not lead to substantial changes in the electricity production mix and therefore replaces the average fossil fuel mix. If we take the average fossil fuel mix as the reference situation for renewables and CHP the impact of policies in this field increases. For the overall results taking the average mix leads to a reduction of CO_2-emission with 6.4% instead of 4.7% when we take a natural gas fired plant as the reference case.

3.9 References

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[8] This effect is not taken into account in the final results, because there are no signicant policies effects observed (volume reduction only last 2 years and no significant improvement of the emission factor (kg N2O/kgN-fertilizer)).
[9] Assumed is that the emission reduction is completely caused by livestock reduction (no improvement of emission factor (kg CH_4/animal)).

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Appendix I: Figures chapter 2

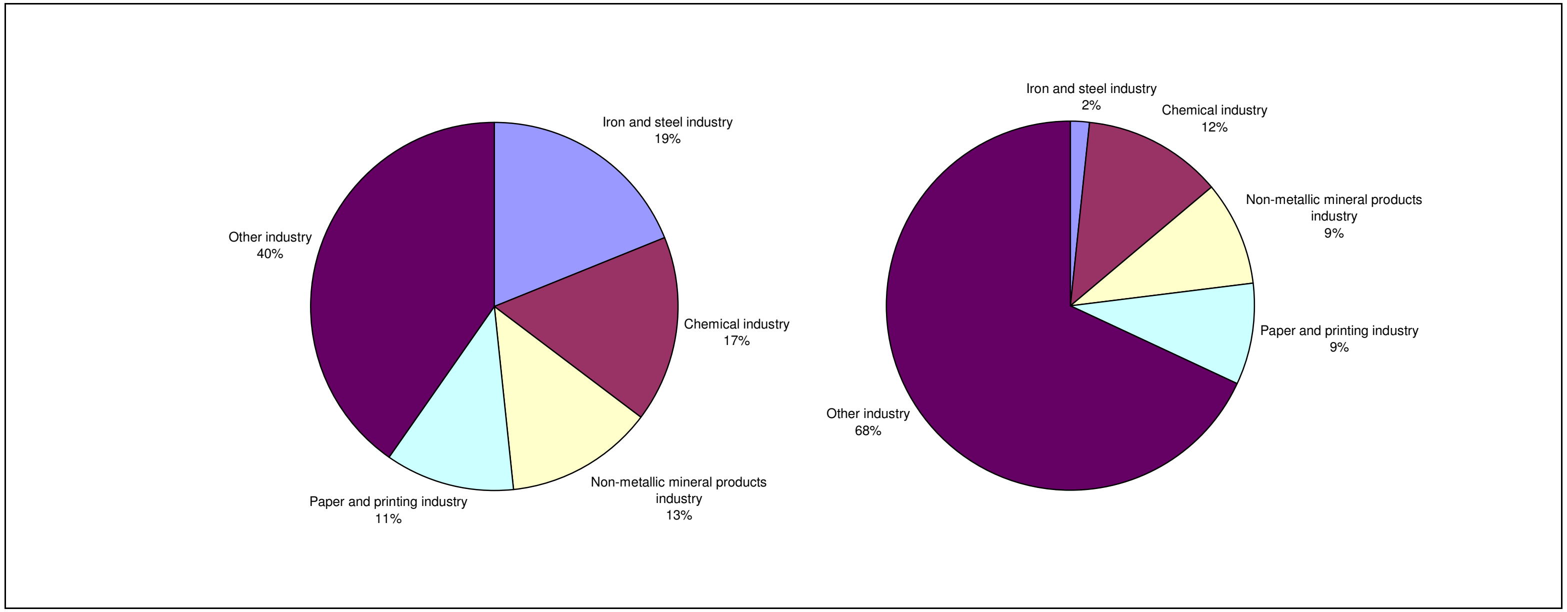

Figure 1 Final energy use (left) and value-added (right) per subsector in industry (EU-15, 2001)

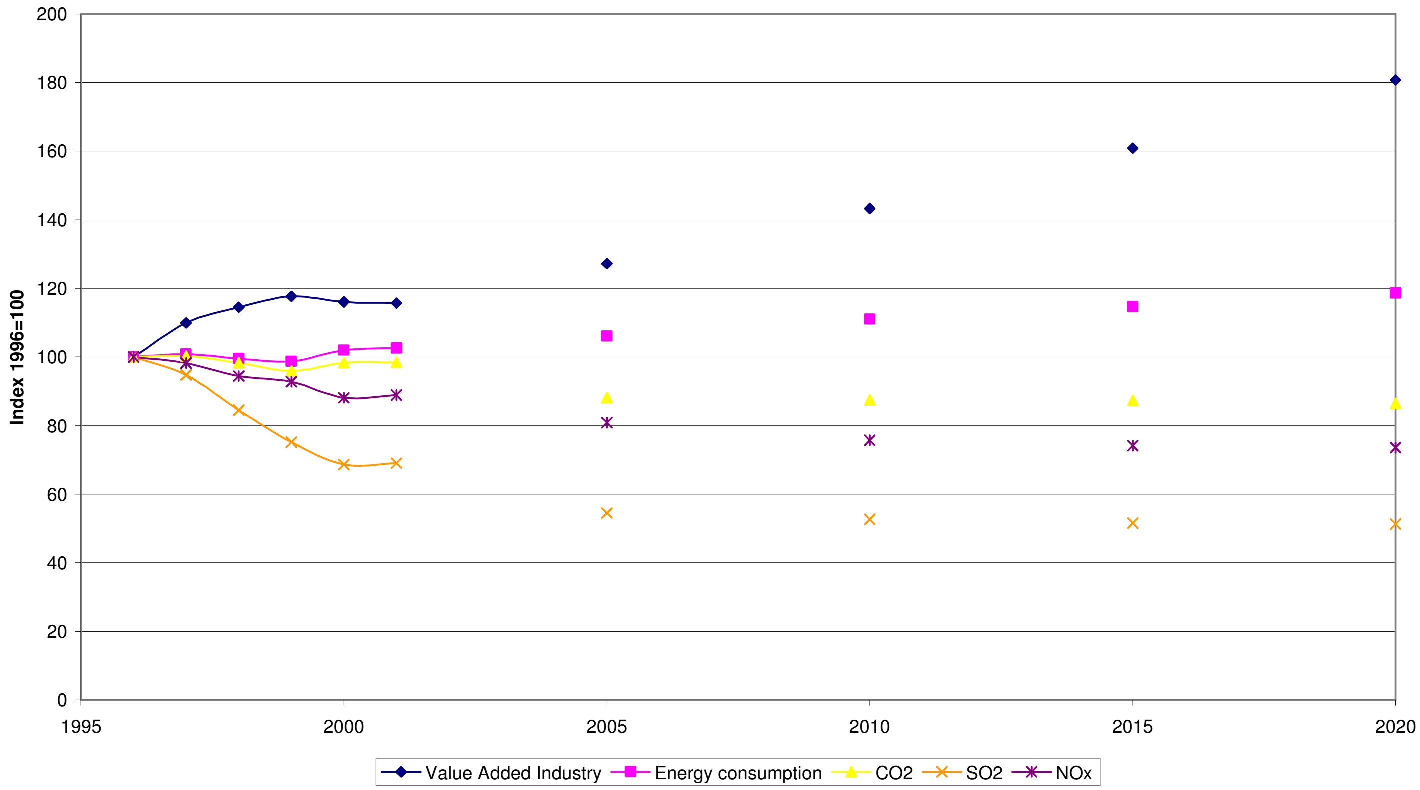

Figure 2 Development of value added, energy consumption and emission of CO_2, SO_2 and NO_x for the EU-25 in the period 1996-2020

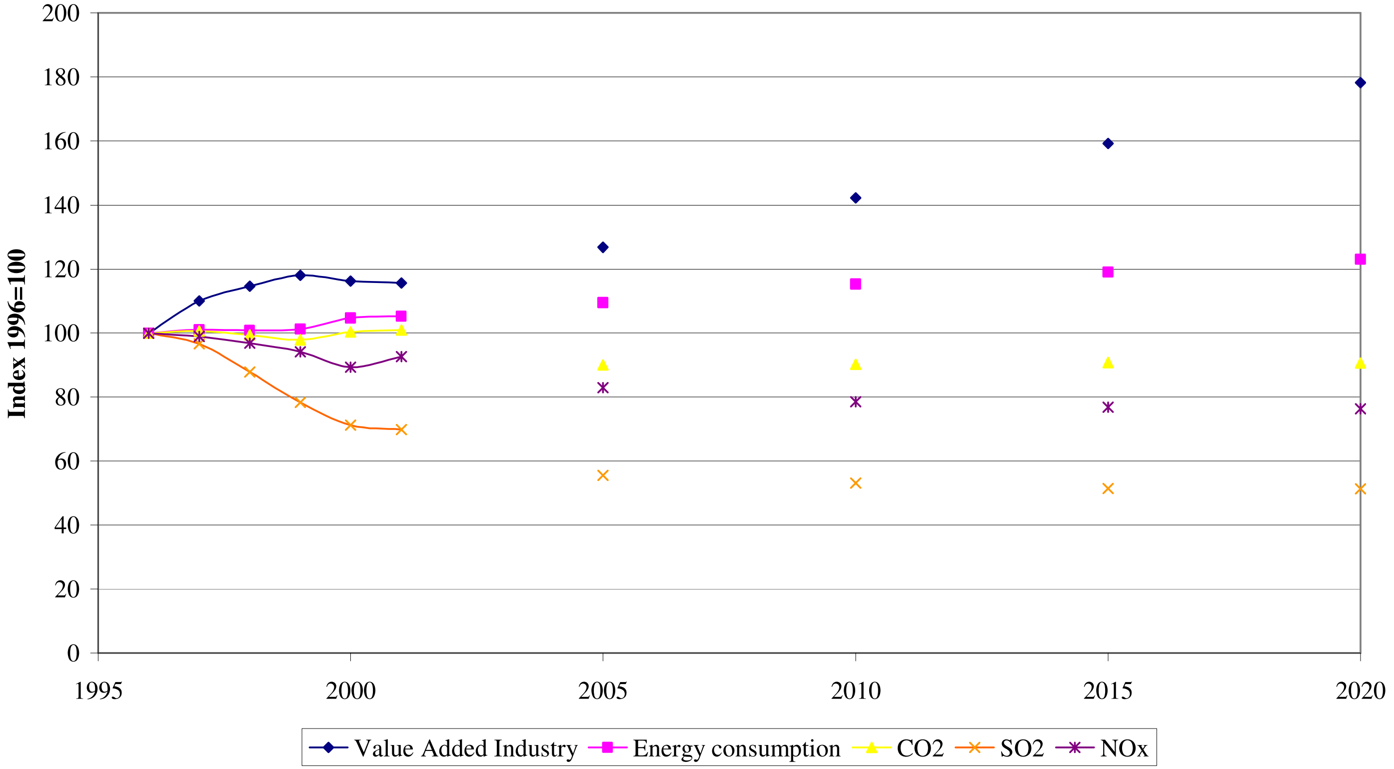

Figure 3 Development of value added, energy consumption and emission of CO_2, SO_2 and NO_x for the EU-15 in the period 1996-2020

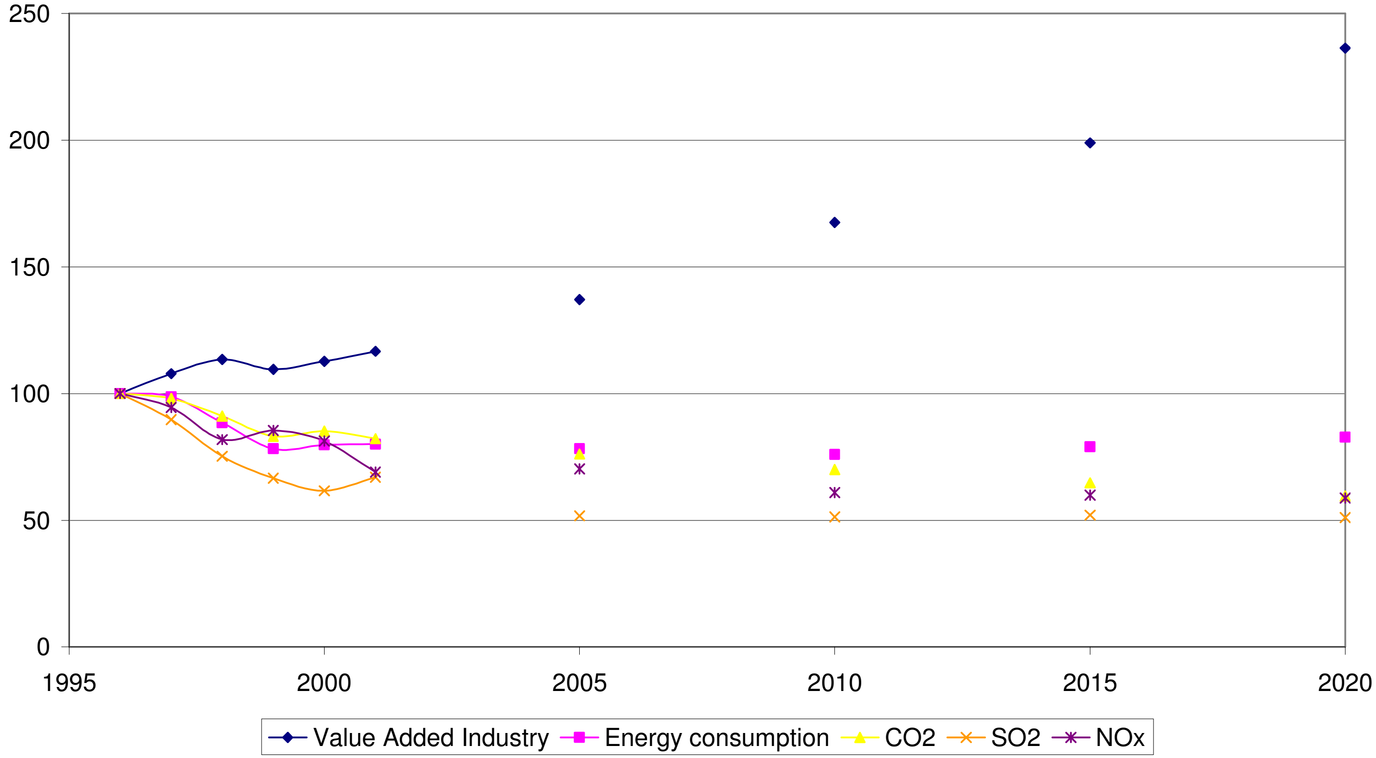

Figure 4 Development of value added, energy consumption and emission of CO2, SO2 and Nox for the New Member States in the period 1996-2020

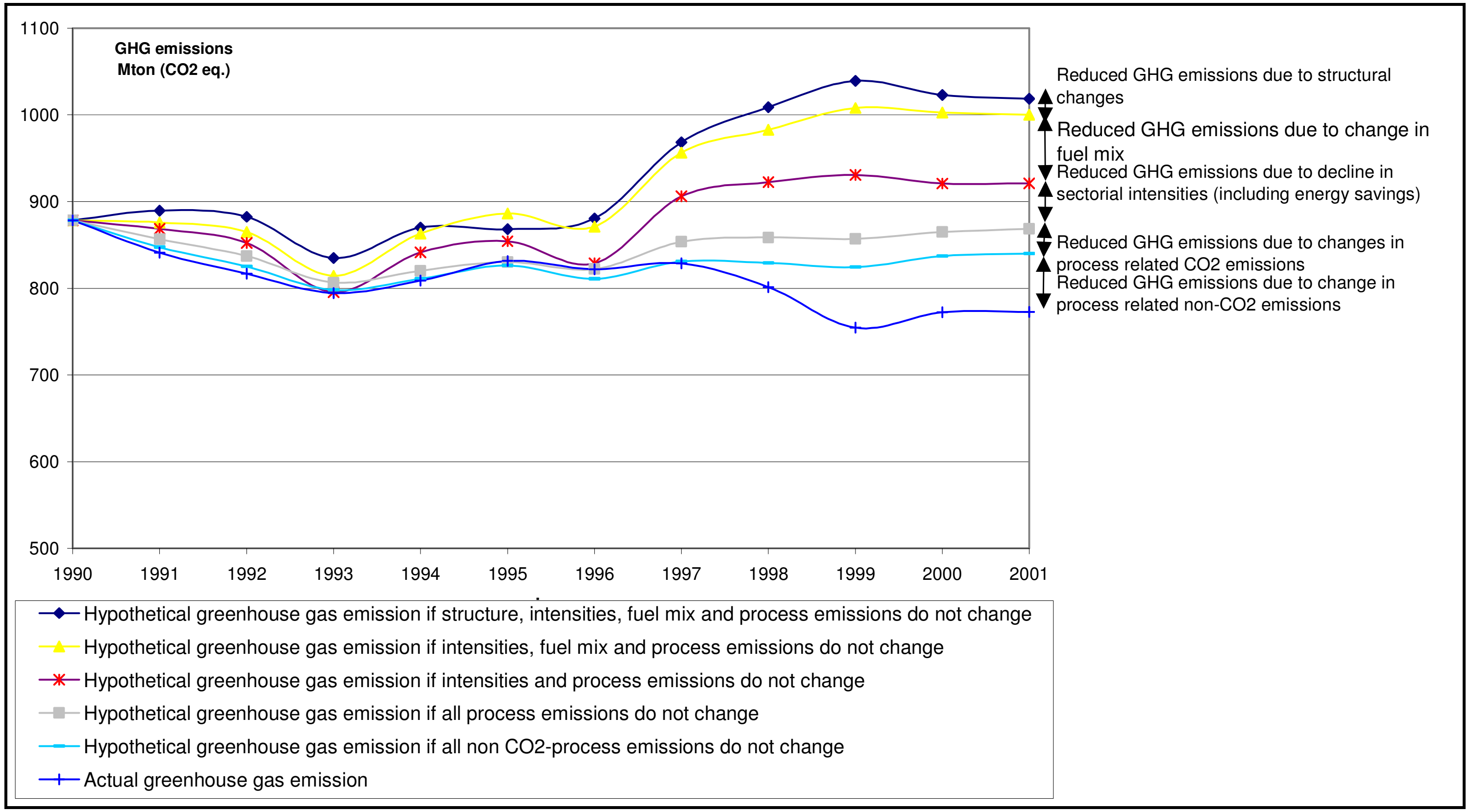

Figure 5 Reduction in GHG emissions from changes in structure, fuel mix, intensity and process related emissions in industry, EU-15, 1990 – 2001

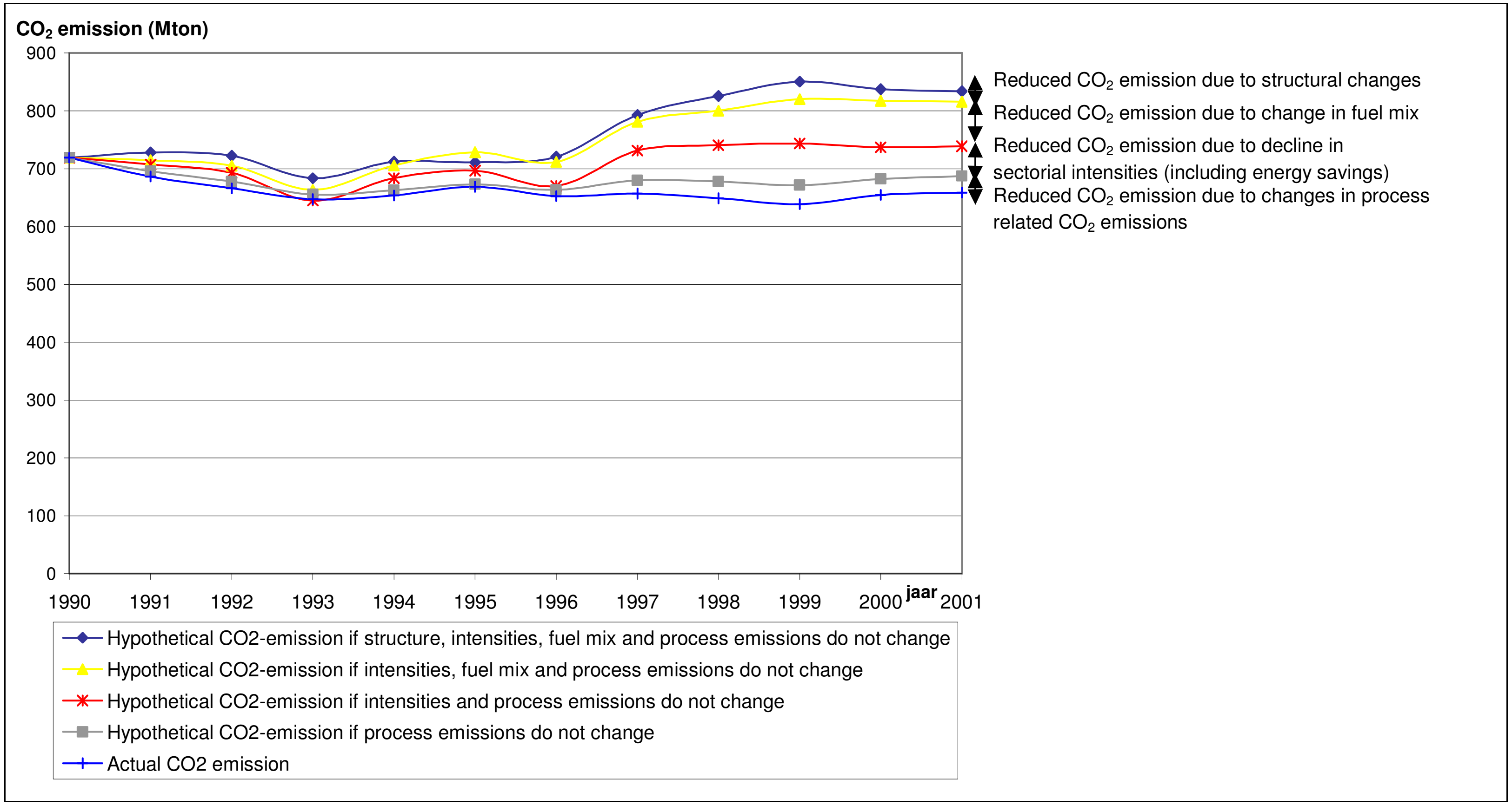

Figure 6 Reduction in CO2 emissions from changes in structure, fuel mix, intensity and process related emissions in industry, EU-15, 1990 – 2001

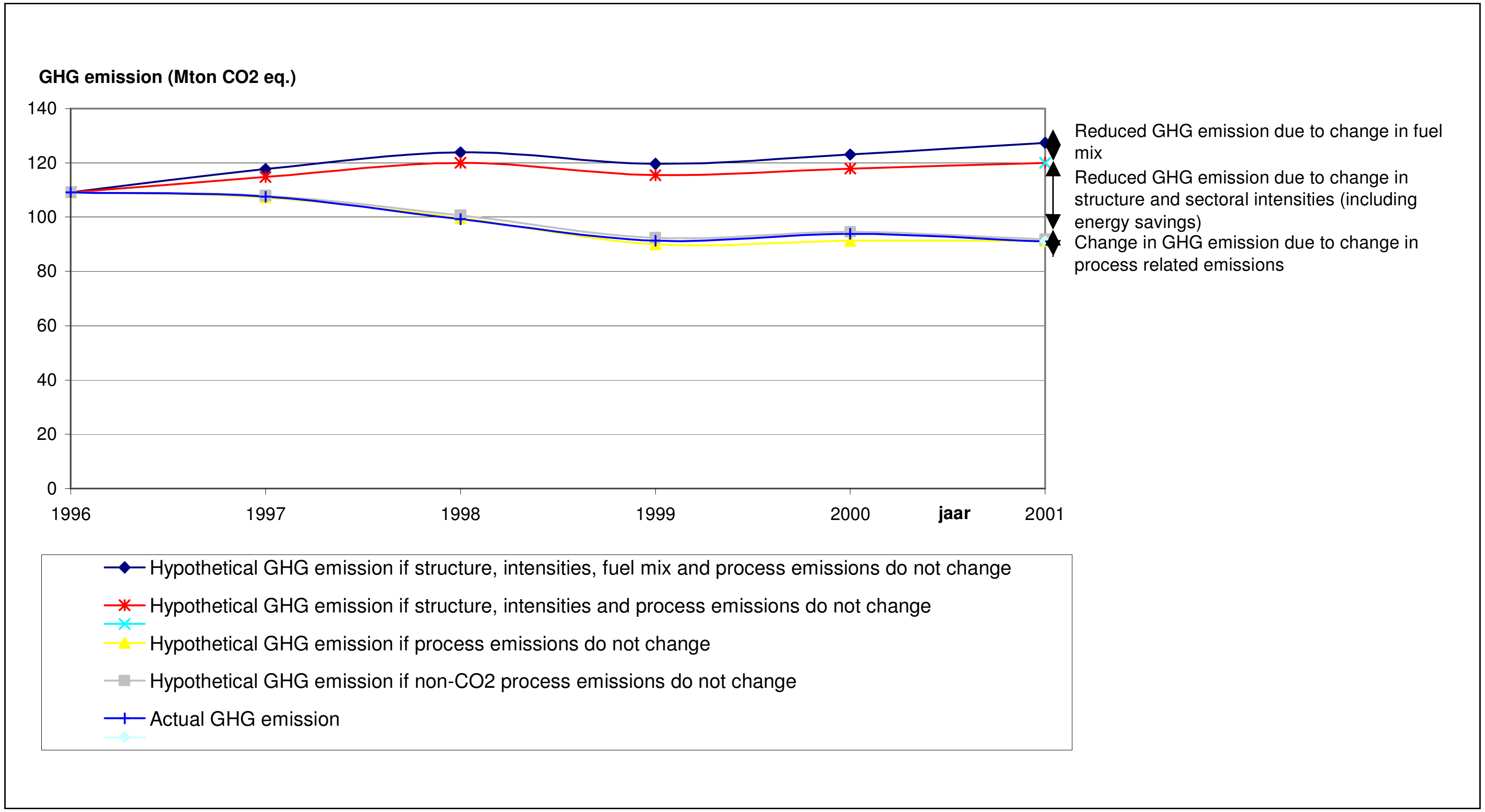

Figure 7 Reduction in GHG emissions from changes in fuel mix, structure and intensity and process related emissions in industry, New Member States, 1996 – 2001

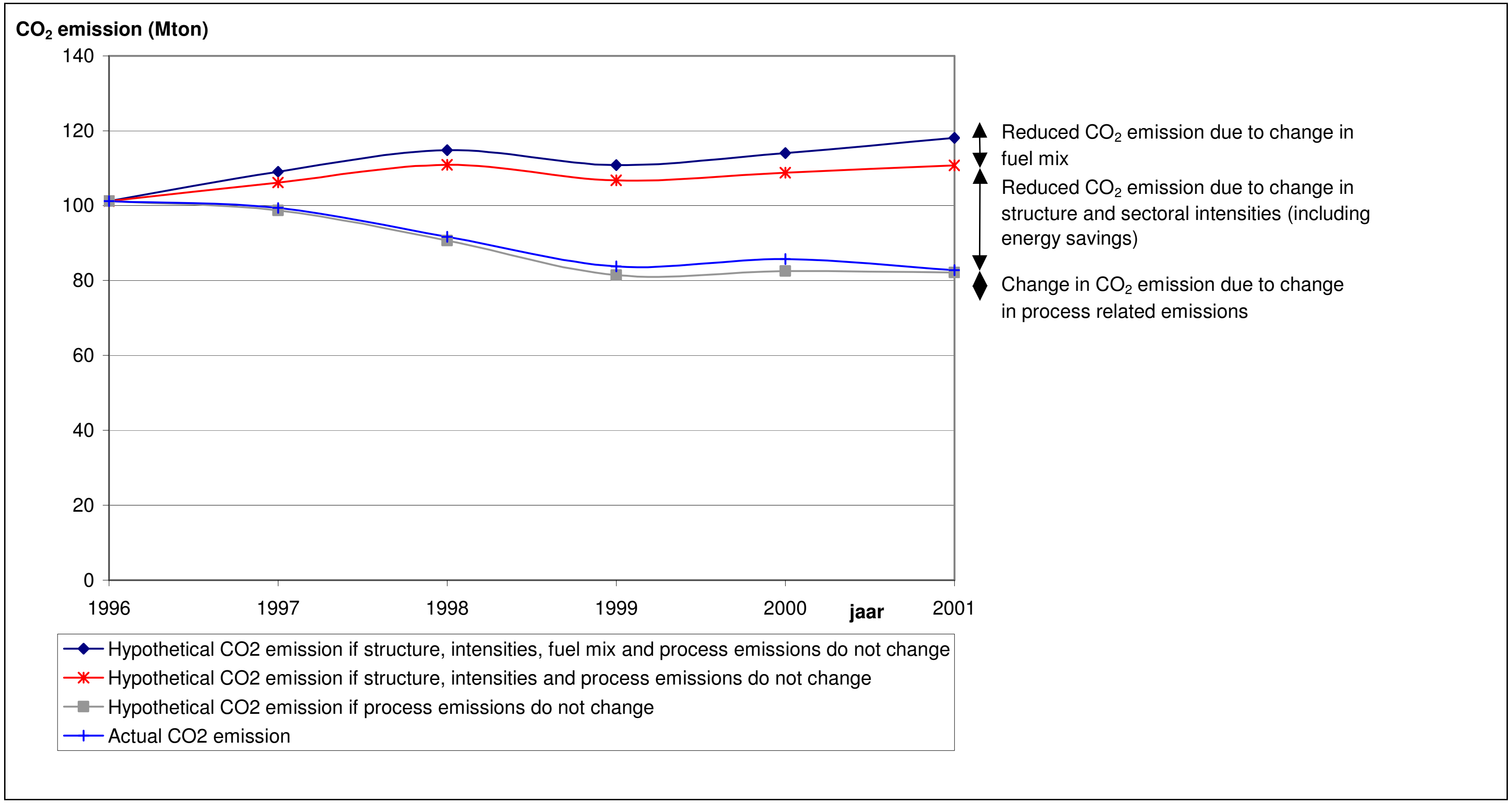

Figure 8 Reduction in CO_2 emissions from changes in fuel mix, structure and intensity and process related emissions in industry, New Member States, 1996 – 2001

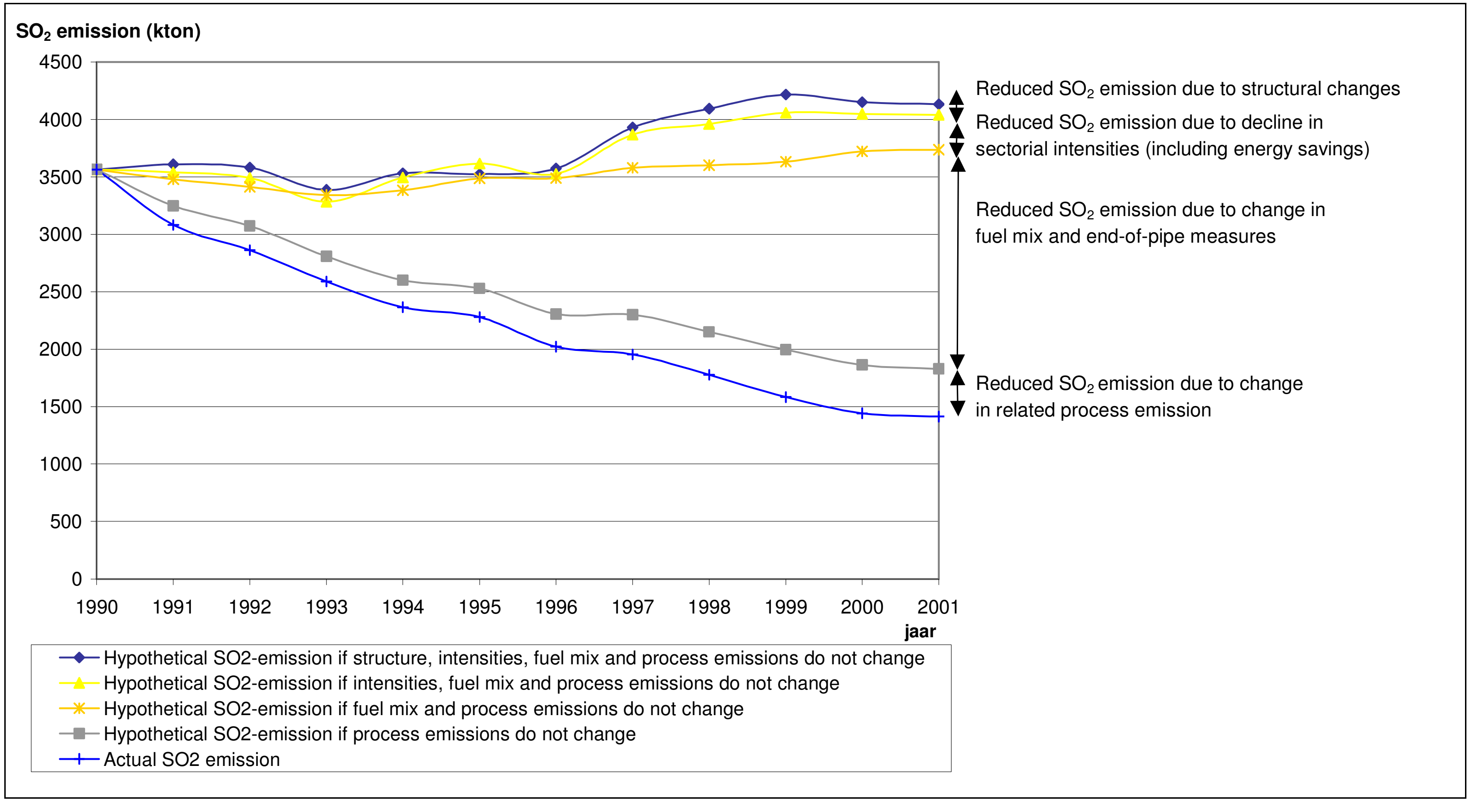

Figure 9 Reduction in SO_2 emissions from changes in structure, intensity, fuel mix and end-of-pipe measures, and process related emissions in industry, EU-15, 1990 – 2001

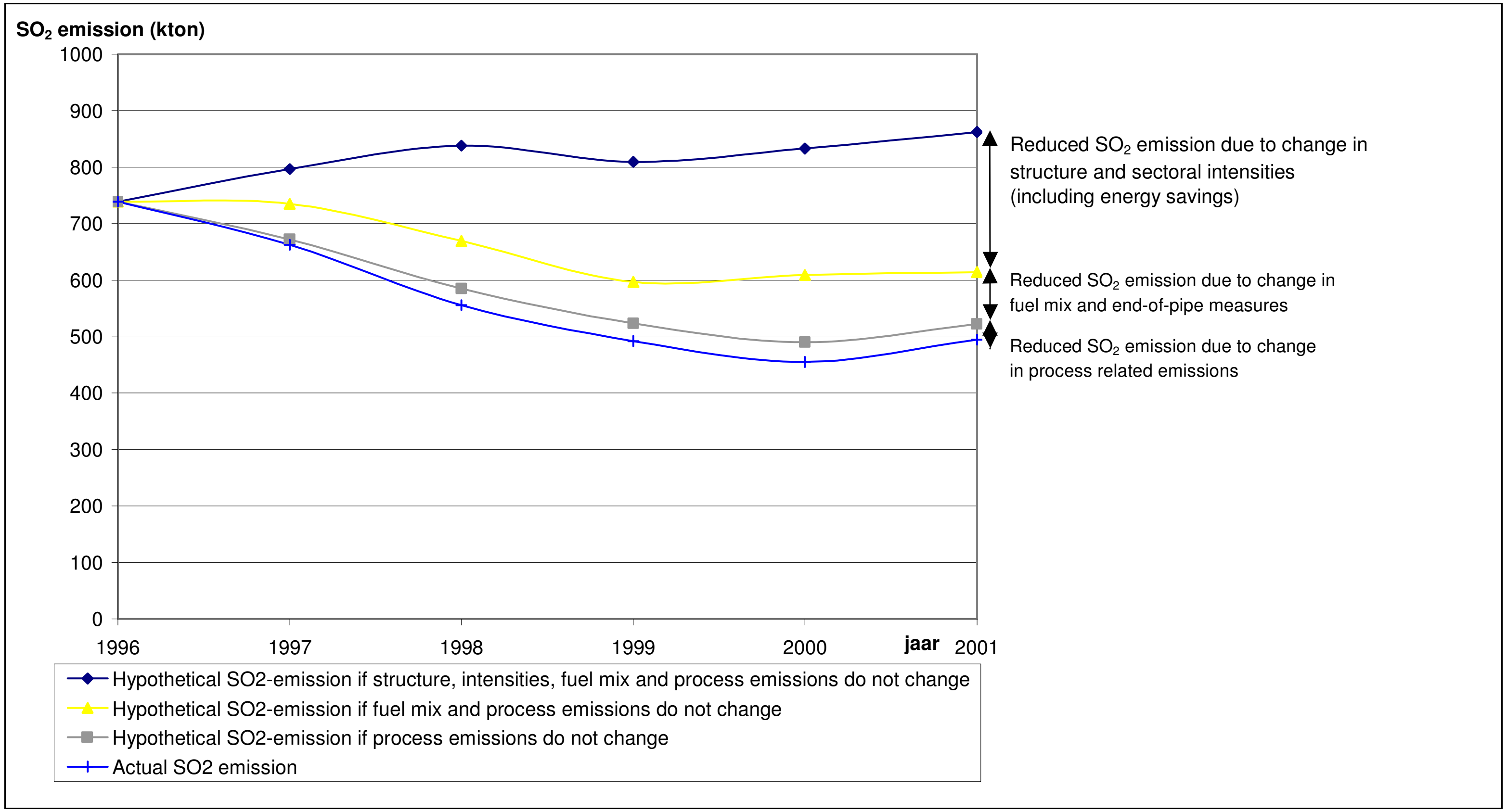

Figure 10 Reduction in SO_2 emissions from changes in structure, intensity, fuel mix and end-of-pipe measures, and process related emissions in industry, New Member States, 1996 – 2001

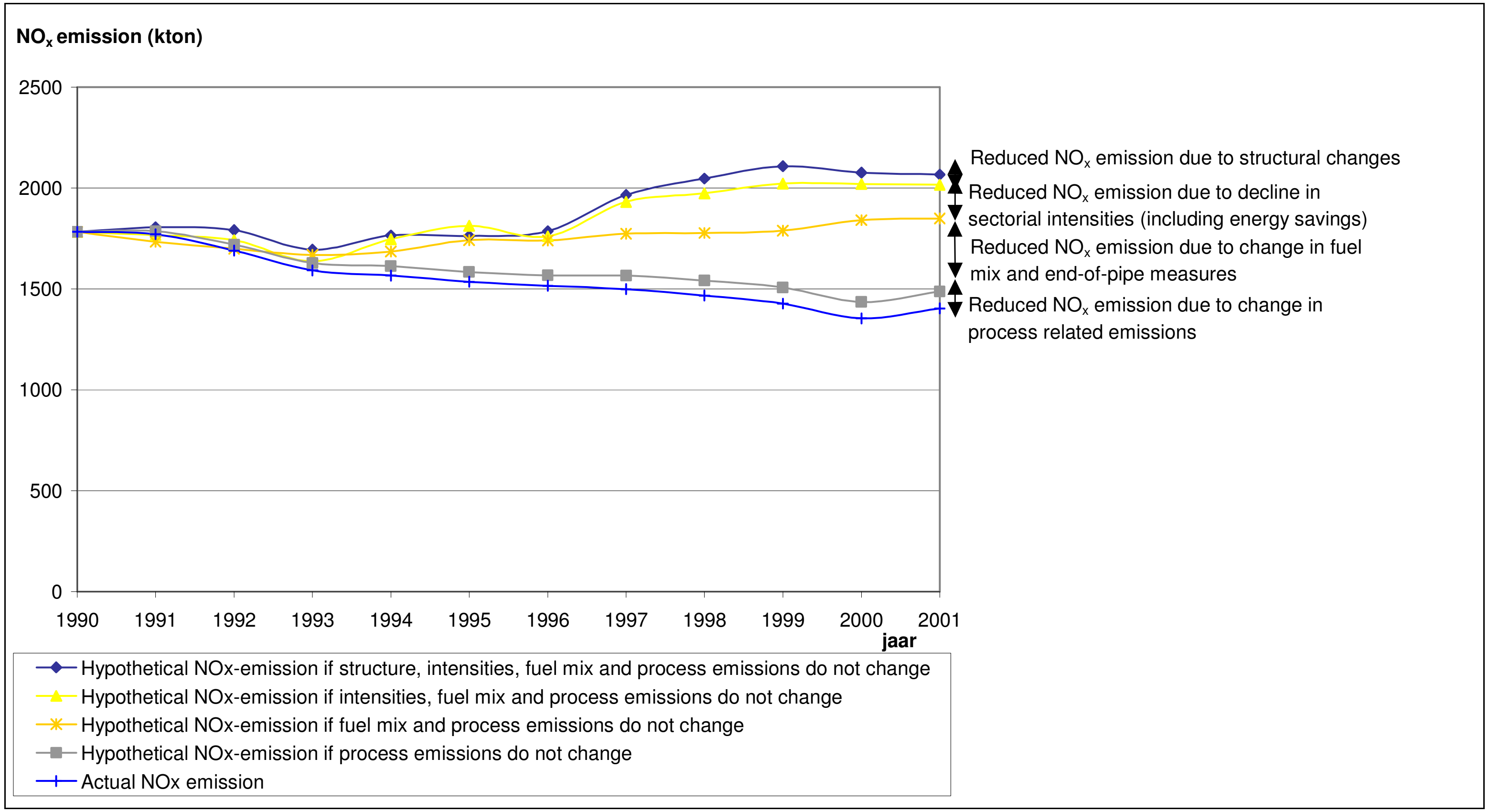

Figure 11 Reduction in NO$_x$ emissions from changes in structure, intensity, fuel mix and end-of-pipe measures, and process related emissions in industry, EU-15, 1990 – 2001

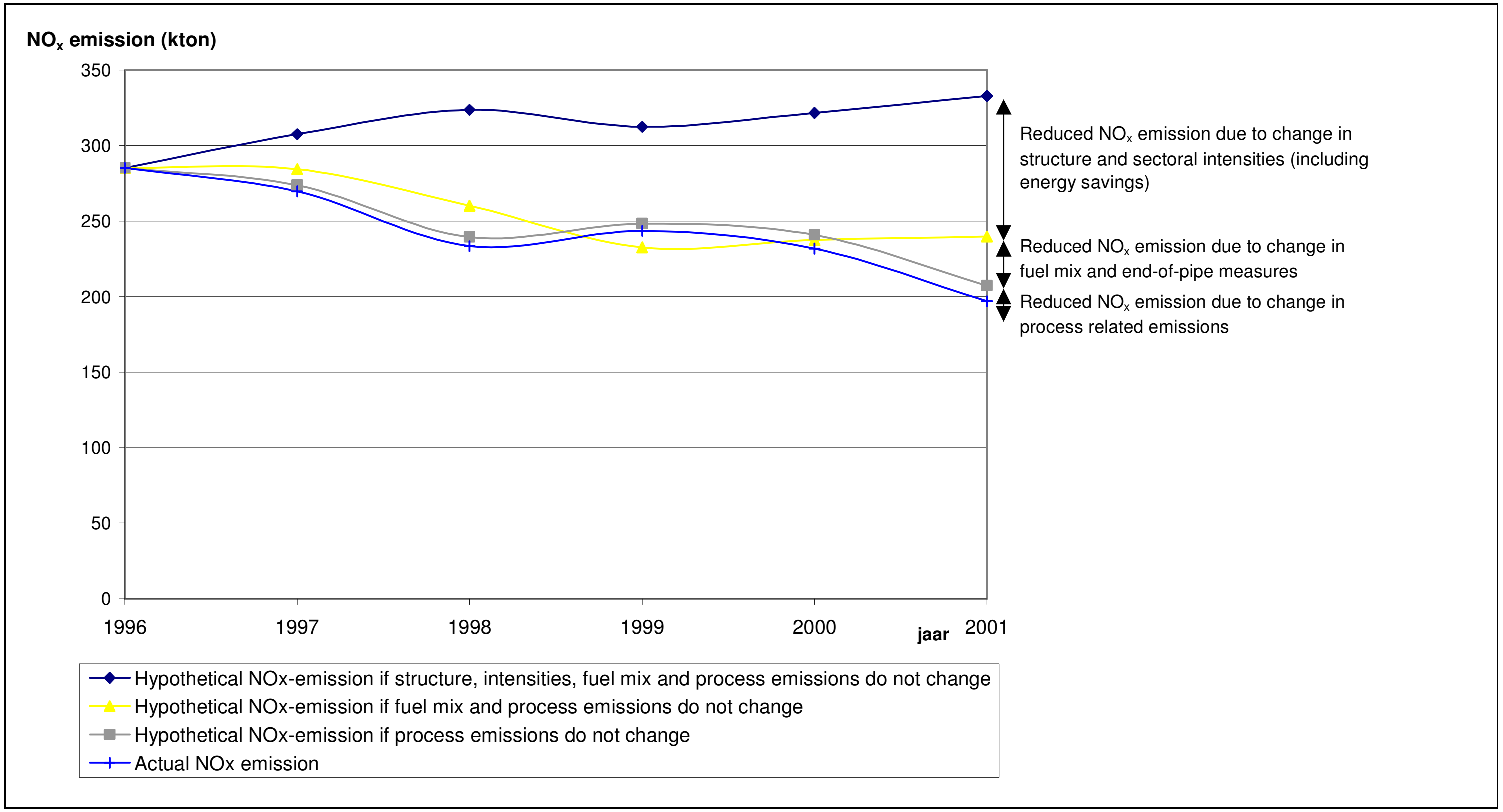

Figure 12 Reduction in NO_x emissions from changes in structure, intensity, fuel mix and end-of-pipe measures, and process related emissions in industry, New Member States, 1996 – 2001

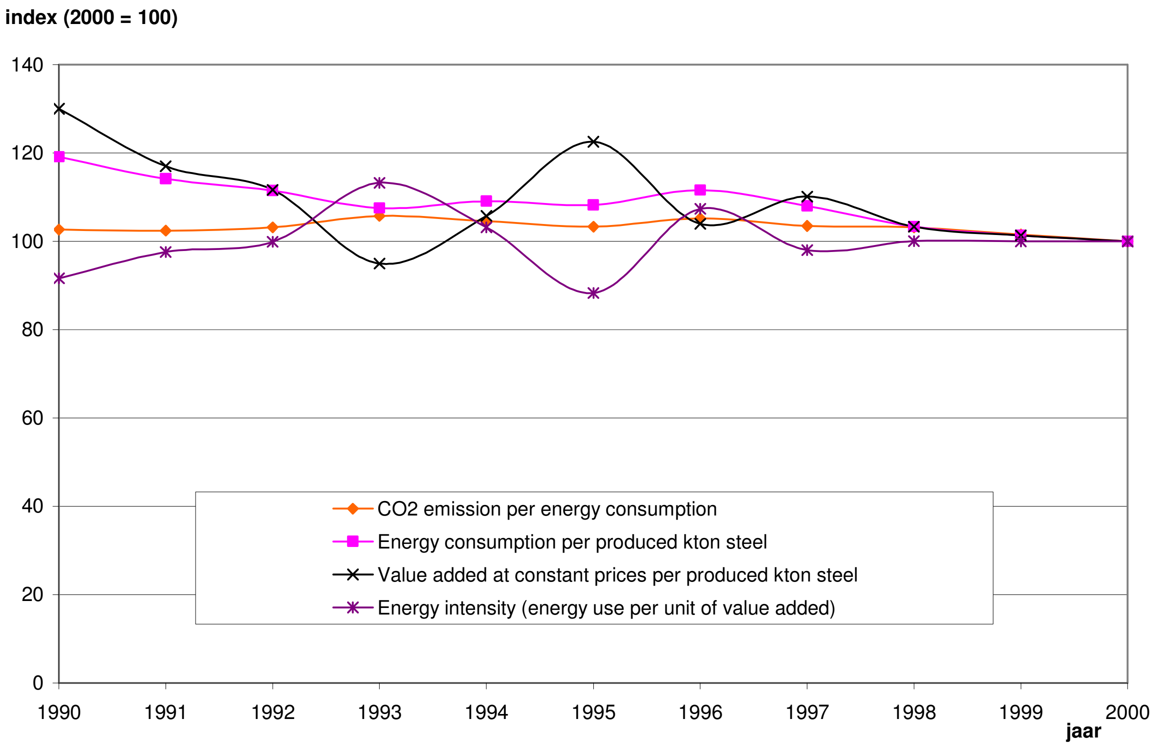

Figure 13 Indices of CO_2 emission, energy and economic activity related indicators in the steel industry in EU-15

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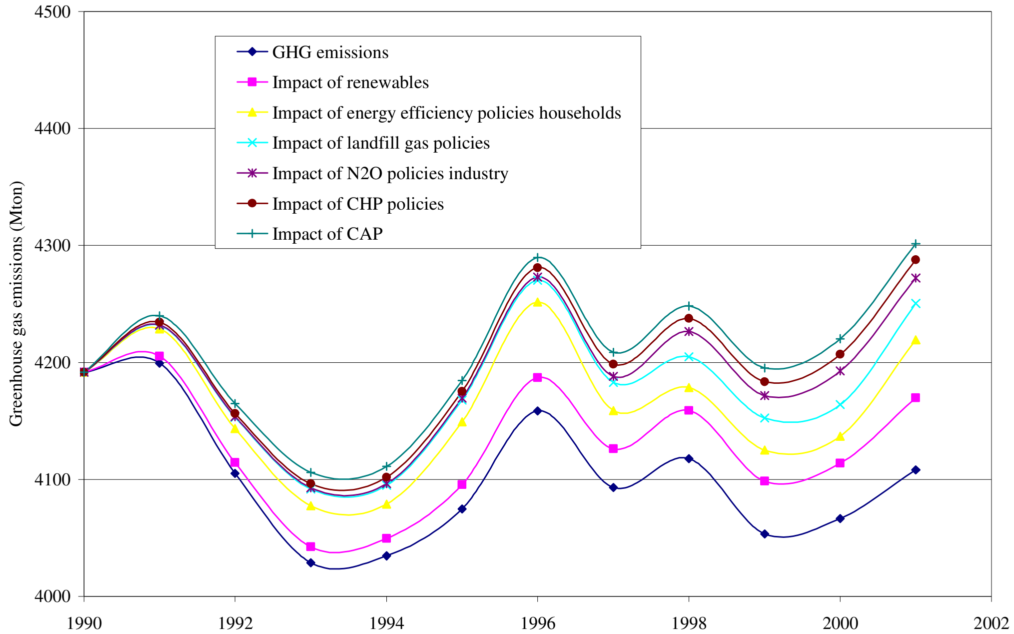

Figure 14 GHG emissions: actual emissions and policy effects on emissions in the EU-15 1990-2001