# EXECUTIVE SUMMARY

Within the EU, industrial activity is an important source of carbon dioxide, accounting for 40% of total direct and indirect carbon dioxide emissions in 1990 and 30% of total greenhouse gas emissions. Greenhouse gases other than $CO_2$ contribute for about 5% to total greenhouse gases emitted in this sector.

Indirect emissions (emissions from steam and electricity production) in this sector play an important role. Emission from energy supply that can be allocated to industry contributes to about 60% of the total emissions in this sector.

## Description of the sector

In the sector industry 9 subsectors are distinguished: iron and steel, non-ferrous metals, chemicals, building materials, paper and pulp, food drink & tobacco, engineering, textiles, and others.

## Frozen technology reference level

The emission reduction potential for 2010 is calculated using an emission reference level based on frozen technology development, assuming that no energy improvement is obtained and that no reduction of specific energy consumption occurs. In the frozen technology reference level greenhouse gas emissions of the industrial sector are about 35% higher (1495 Mt in 1990 compared to about 2007 Mt of $CO_2$ equivalent in 2010). Table 1 gives an overview of the emission levels of $CO_2$ for the subsectors.

*Table 1. 1990 energy use, and direct (including process emission) and indirect emission (steam and electricity consumption related) of $CO_2$ (in Mt $CO_2$), and 2010 frozen technology reference level (2), thus excluding effects by efficiency improvements, fuel shift and intrasubsectoral product shifts. Fuel use, emissions and projections on industrial production grow rates are taken from Primes [1999]. Figures in italics refer to own estimate.*

| (Sub)sector | 1990 Fuel use | Direct CO2 emission | Indirect CO2 emission | 1990 total CO2 emissions | 2010 frozen technology reference level |
|---|---|---|---|---|---|
| | EJ | Mt | Mt | Mt | Mt |
| Iron and Steel | 2.3 | 198 | 48 | 246 | 266 |
| Non-ferrous metals | 0.5 | 16 | 33 | 50 | 68 |
| Chemicals | 2.0 | 38 | 217 | 254 | 420 |
| Building materials | 1.5 | 204 | 28 | 232 | 276 |
| Paper, pulp and printing | 1.0 | 10 | 124 | 135 | 218 |
| Food, drink, tobaco | 0.9 | 11 | 96 | 107 | 166 |
| Others | 1.0 | 104 | 160 | 264 | 374 |
| **Total** | **9.3** | **581** | **706** | **1287** | **1789** |

All emission data refer to $CO_2$ only. Inclusion of non-$CO_2$ greenhouse emissions increase total greenhouse gas emissions by 16% for 1990 and 12% for 2010 frozen technology reference level.

Besides emission of $CO_2$ a number of industrial activities cause emissions of other greenhouse gases like nitrous oxide and fluorinated gases, and to a lesser extent methane.

## Emission reduction options

In this study emission reduction options are identified to reduce emissions of industrial carbon dioxide, to reduce nitrous oxide emissions from the nitric acid and adipic acid manufacture and to reduce emissions from fluorinated gases.[1]

In this study the potentials for energy efficiency improvement are determined at the level of industrial subsectors. Only emission reduction options are included that have a high probability of being commercially available before 2010. Options regarding implementation of new capacity are defined based on technology with an efficiency level equal to the best practice value of 1995. In many cases a shift to another product mix (e.g. primary steel to secondary steel) might entail the potential to reduce emissions further. However, these intra-industrial structural changes are not considered in this bottom-up study.

Table 3 gives an overview of the investment costs, the yearly costs (sum of operation and maintenance costs and savings), average specific mitigation costs and potential for options applicable in the industry sector. The specific costs are calculated using a real interest rate of 4% and using the lifetime of the option, i.e. equipment. The technical reduction potential of all greenhouse gases is estimated at about 533 Mt of $CO_2$ equivalent. Including the technical emission reduction potential of the energy supply sector the reduction amounts to 1000 Mt of $CO_2$ equivalent or about 50% of total direct and indirect industrial emissions.

## Summary

Table 2 summarises the frozen technology reference level in the industry and shows the position if all the options in the table above were adopted.

*Table 2. Summary of total direct and indirect emissions in industry (Mt $CO_2$ equivalent).*

| | **1990** | **2010 frozen technology reference level** | **2010 with all options** |
|---|---|---|---|
| *Carbon dioxide* | 1287 | 1789 | 905 |
| *Methane* | 3 | 3 | 3 |
| *Nitrous oxide* | 143 | 135 | 47 |
| *Fluorinated gases* | 63 | 81 | 31 |
| **Total** | **1495** | **2007** | **985** |

Figure 1 shows the share in emission reduction categorised in four cost brackets.

[1] The options to reduce emission of fluorinated gases are not described in this report but in the report "Economic Evaluation of Emission Reductions of HFCs, PFCs and $SF_6$ in Europe", J. Harnisch and C. Hendriks, Ecofys, March 2000.

*Table 3. EU15-average costs and total potential (Mt of $CO_2$ equivalent) for industrial emission reduction options.*

| Pollutant | Measure Name | Sector | Emission reduction | Investment | Yearly costs | Lifetime | Specific abatement costs |
|---|---|---|---|---|---|---|---|
| | | | Mt CO2 eq. | euro/tCO2 eq. | euro/tCO2 eq. | year | euro/tCO2 eq. |
| CO2 | Application of continuous casting | Integrated iron and steel plant | 1 | 557 | -280 | 15 | -230 |
| | Improved process control | Minimills | 2 | 284 | -274 | 15 | -76 |
| | Miscellaneous | Petrochemicals | 0.5 | 187 | -92 | 15 | -75 |
| | Debottlenecking | Petrochemicals | 6 | 187 | -92 | 15 | -75 |
| | Miscellaneous I (Low cost tranche) | Pulp | 2 | 200 | -47 | 15 | -67 |
| | Micellaneous II (High cost tranche) | Pulp | 2 | 1973 | -271 | 15 | -58 |
| | Process integration, e.g. by applying pinch technology | Petrochemicals | 0.3 | 187 | -54 | 15 | -56 |
| | Ceramics - new capacity | Ceramics | 3 | 0 | -71 | 15 | -54 |
| | Miscellaneous I (Low cost tranche) | Other industry | 54 | 200 | -47 | 15 | -53 |
| | Electricity savings | Glass | 0.2 | 1151 | -271 | 15 | -50 |
| | Fractionation - various options | Petrochemicals | 0.3 | 469 | -92 | 15 | -50 |
| | Miscellaneous I (Low cost tranche) | Other Chemicals | 38 | 200 | -47 | 15 | -49 |
| | Food, beverages and tobacco - micellaneuous I (Low cost tranche) | Other Food | 20 | 216 | -66 | 15 | -49 |
| | Miscellaneous | Ceramics | 11 | 187 | -92 | 15 | -47 |
| | Glass - new capacity | Glass | 0.4 | 0 | -51 | 15 | -45 |
| | Miscelleneous - building materials | Other Building materials | 6 | 188 | -63 | 15 | -44 |
| | Raising cullet percentage in raw material | Glass | 1 | 0 | -44 | 15 | -44 |
| | Paper - New capacity | Paper | 8 | 0 | -45 | 15 | -43 |
| | Electricity savings | Cement | 1 | 1151 | -271 | 15 | -39 |
| | Cement - new capacity | Cement | 5 | 0 | -41 | 15 | -38 |
| | Process integration, e.g. by applying pinch technology | Fertilisers | 0.1 | 187 | -54 | 15 | -37 |
| | Food, beverages and tobacco - micellaneuous II (High cost tranche) | Other Food | 28 | 532 | -62 | 15 | -35 |
| | Miscellaneous I (Low cost tranche) | Paper | 14 | 200 | -47 | 15 | -35 |
| | Reduce clinker content of cement | Cement | 1 | 0 | -34 | 15 | -34 |
| | Improving wet process kilns | Cement | 2 | 0 | -34 | 15 | -34 |
| | Use of waste derived fuels | Cement | 3 | 7 | -34 | 15 | -33 |
| | Optimisation of heat recovery of clinker cooler | Cement | 1 | 29 | -34 | 15 | -31 |
| | Pulverised coal injection up to 30% in the blast furnace (primary steel) | Integrated iron and steel plant | 1 | 200 | -48 | 15 | -30 |
| | Efficient CO2-separation (e.g. by using membranes) | Fertilisers | 0.03 | 281 | -54 | 15 | -29 |
| | Improved drying, e.g. condensing belt drying | Paper | 1 | 52 | -30 | 15 | -28 |
| | Miscellaneous II (High costtranche) | Paper | 11 | 667 | 0 | 15 | -26 |
| | Cracking furnace - variuous options | Petrochemicals | 0.2 | 750 | -90 | 15 | -23 |
| | Miscellaneous II (High costtranche) | Other industry | 54 | 667 | 0 | 15 | -22 |
| | Miscellaneous | Sugar | 4 | 187 | -92 | 15 | -12 |
| | Other non-ferro metals - miscellaneuous | Other non-ferro | 10 | 385 | -46 | 15 | -11 |
| | Batch and cullet preheating | Glass | 1 | 269 | -35 | 15 | -11 |
| | Miscellaneous II (High costtranche) | Other Chemicals | 33 | 667 | 0 | 15 | -11 |
| | Application of multi-stage preheaters and pre-calciners | Cement | 0.2 | 673 | -70 | 15 | -10 |
| | Pressing to higher consistency, e.g. by extended nip press (paper making) | Paper | 5 | 267 | -20 | 15 | -9 |
| | Application of efficient evaporation processes (dairy) | Dairy | 1 | 567 | -31 | 15 | -8 |
| | Reduced air requirements, e.g. by humidity control in paper machine drying hoods | Paper | 6 | 361 | -21 | 15 | -6 |
| | **Subtotal: Cost range < 0 euro / t CO2 eq.** | | **334** | | | | |
| | Integrated mills - new capacity | Integrated iron and steel plant | 2 | 0 | 0 | 15 | 0 |
| | Scrap preheating in electric arc furnaces (secondary steel) | Minimills | 0.3 | 0 | 0 | 15 | 0 |
| | Oxygen en fuel injection in electric arc furnaces (secondary steel) | Minimills | 1 | 0 | 0 | 15 | 0 |
| | Minimills - new capacity | Minimills | 15 | 0 | 0 | 15 | 0 |
| | Replacement of mercury and diaphragm processes by membrane electrolysis (chlorine) | Other chemicals | 6 | 0 | 0 | 15 | 0 |
| | Miscellaneous I (Low cost tranche) | Iron and steel | 12 | 200 | -47 | 15 | 2 |
| | Refiner improvements | Pulp | 1 | 752 | -30 | 15 | 2 |
| | Improved melting technique and furnace design | Glass | 1 | 366 | -29 | 15 | 4 |
| | Low pressure ammonia synthesis | Fertilisers | 0.01 | 469 | -37 | 15 | 5 |
| | Fertilisers - new capacity | Fertilisers | 0.2 | 469 | -37 | 15 | 5 |
| | Gas turbine integration | Fertilisers | 0.2 | 750 | -56 | 15 | 11 |
| | **Subtotal: Cost range 0 < 20 euro / t CO2 eq.** | | **38** | | | | |
| | Heat recovery in TMP | Pulp | 7 | 79 | 30 | 15 | 31 |
| | Thin slab casting techniques | Iron and steel | 1 | 802 | -39 | 15 | 33 |
| | Recovery of process gas from coke ovens, blast furnaces and basic oxygen furnaces (primary steel) | Integrated iron and steel plant | 1 | 347 | 5 | 15 | 36 |
| | Miscellaneous II (High costtranche) | Iron and steel | 11 | 667 | 0 | 15 | 47 |
| | Subtotal: Cost range 20 < 50 euro / t CO2 eq. | | 20 | | | | |
| | Advanced reforming | Fertilisers | 0.1 | 1218 | -45 | 15 | 65 |
| | Retrofit existing Hall-Héroult process (e.g. alumina point-feeding, computer control) | Aluminium | 0.5 | 6330 | -274 | 15 | 72 |
| | Efficient production of low-temperature heat (heat recovery from high-temperature processes) | Integrated iron and steel plant | 2 | 1694 | -18 | 15 | 135 |
| | Wettable cathode | Aluminium | 0.4 | 18086 | -274 | 15 | 328 |
| | **Subtotal: Cost range > 50 euro / t CO2 eq.** | | **3** | | | | |

| Pollutant | Measure Name | Sector | Emission reduction | Investment | Yearly costs | Lifetime | Specific abatement costs |
|---|---|---|---|---|---|---|---|
| | | | Mt CO2 eq. | euro/tCO2 eq. | euro/tCO2 eq. | year | euro/tCO2 eq. |
| N2O | Industrial processes Adipic acid | Chemical industry | 66 | 232 | 24 | 15 | 0.1 |
| | Industrial processes Nitric acid | Chemical industry | 22 | 238 | 106 | 15 | 0.4 |
| | **Subtotal: Cost range 0 < 20 euro / t CO2 eq.** | | **89** | | | | |
| HFC | Industrial refrigeration: hydrocarbons and NH3 | Food, Drink & Tobacco | 1 | 36 | -12 | -9 | -9 |
| | Subtotal: Cost range < 0 euro / t CO2 eq. | | 1 | | | | |
| | Oxidation of HFC-23 | Chemical industry | 7 | 1 | 0.1 | 15 | 0.2 |
| | Foam PU-one component: hydrocarbons | Other industry | 3 | 4 | 0 | 15 | 0.4 |
| | Foam PU-pipe in pipe: pentane | Other industry | 0.1 | 27 | 0 | 15 | 2 |
| | Industrial food refrig.: hydrocarbons and NH3 | Food, Drink & Tobacco | 2 | 164 | -12 | 15 | 3 |
| | Foams XPS: carbon dioxide | Other industry | 6 | 11 | 5 | 15 | 6 |
| | Aerosols: hydrocarbons | Other industry | 2 | 85 | 3 | 15 | 10 |
| | Foam PU-spray: water | Other industry | 1 | 6 | 18 | 15 | 18 |
| | Subtotal: Cost range 0 < 20 euro / t CO2 eq. | | 23 | | | | |
| | Foam PU-flexible faced laminate: pentane | Other industry | 1 | 11 | 20 | 15 | 21 |
| | Foam PU-discontinuous panels: pentane | Other industry | 1 | 45 | 23 | 15 | 27 |
| | Foam PU-blocks: pentane | Other industry | 1 | 104 | 18 | 15 | 27 |
| | Foam PU-continuous panels: pentane | Other industry | 0.2 | 13 | 31 | 15 | 32 |
| | **Subtotal: Cost range 20 < 50 euro / t CO2 eq.** | | **2.6** | | | | |
| | Foam PU-appliances: pentane | Other industry | 0.2 | 107 | 54 | 15 | 63 |
| | **Subtotal: Cost range > 50 euro / t CO2 eq.** | | **0.2** | | | | |
| PFC | Aliminium: Side worked pre-baked anode cell (SWPB) conversion | Non-ferrous Metals | 5 | 39 | -6 | 15 | -2 |
| | Semiconductors: etch - alternative chemicals | Other industry | 1 | 0 | 0 | 15 | 0.0 |
| | Aluminium: Vertical stud Soderberg anode (VSS) retrofit | Non-ferrous Metals | 0.3 | 39 | -3 | 15 | 1 |
| | Semiconductors: Chemical vapour deposition (CVD), NF3 | Other industry | 10 | 49 | 23 | 15 | 28 |
| | Semiconductors: etch - oxidation | Other industry | 3 | 79 | 71 | 15 | 79 |
| | **Subtotal: All cost ranges** | | **20** | | | | |
| SF6 | Magnesium production: use of SO2 as protection gas | Non-ferrous Metals | 3 | 4 | 0 | 15 | 0.3 |
| | **Subtotal: Cost range 0 < 20 euro / t CO2 eq.** | | **3** | | | | |

| | |
|---|---|
| Cost range < 0 euro / t CO2 eq. | 340 |
| Cost range 0 < 20 euro / t CO2 eq. | 153 |
| Cost range 20 < 50 euro / t CO2 eq. | 33 |
| Cost range > 50 euro / t CO2 eq. | 6 |
| **Total emission reduction potential** | **533** |

*Figure 1. 1990 base year emissions (left, by gas) and 2010 frozen technology reference level (right, by cost bracket). The specific costs are calculated assuming a real interest rate of 4%. In all the cases the emissions are total emissions, i.e. direct emissions from the sector and indirect emissions (emissions from steam and electricity production allocated to the sector). The emission reduction potential includes the emission reduction attainable in the energy supply sector which can be allocated to the industry, based on its steam and electricity consumption.*