EPM MODEL : EMISSION PROJECTION OF GREENHOUSE GASES IN BELGIUM IN 2010

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Executive Summary

In the framework of the project “Analysis of emission reduction options for greenhouse gases and tropospheric ozone precursors”, ECONOTEC’s mission has consisted in continuing the development of the EPM (Emissions Projection Model) model, by making a new version of it in a database environment, and in applying the model to make a contribution to the preparation of emission reduction policies.

In a first phase, the efforts have been on NOx and VOC emissions. The results of these activities have been valorised in the framework of the preparation of the Gothenburg Protocol[1] and the European directive on national emission ceilings[2].

The second part of the research has been devoted to the main greenhouse gases concerned by the Kyoto Protocol, i.e., CO2, CH4 and N2O. The priority has been given to CO2, which relates to all economic activities and which, in tonnes of CO2-equivalent, represents over 80% of the total greenhouse gas emissions.

The tasks carried out have consisted in:

- the informatic data organisation, which has led to a complete reformulation of the model (from spreadsheets to the Access database software), which has significantly increased the model’s performance;
- the data collection and validation;
- the use of the model for constructing reference (business-as-usual) emission scenarios and the evaluation of emission reduction potentials of the various gases concerned.

The report describes the main characteristics of the EPM model and presents results of an emission projection analysis for CO2 and the other greenhouse gases in Belgium in 2010 (reference scenario, emission reduction potential).

A bottom-up model

The EPM model is a projection model of the energy demand and the main atmospheric pollutants, which covers the various sectors concerned (industry, residential, tertiary,

[1] Protocol to the United Nations Convention on Long Range Atmospheric Pollution (CLRTAP).
[2] Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants.

transportation). It has been developed progressively by ECONOTEC since 1993 in the framework of a range of studies carried out for the public authorities, as well at the national as at the regional level.

Given the heterogeneity of “sectors” such as the iron & steel industry, the chemical industry or the residential sector, one must, in order to be able to make a good projection, take into account the internal structural effects of these sectors, that is the differential evolution of the main sub-sectors or production processes (for example the different workshops of the iron & steel industry), as far as their specific energy consumptions are different.

EPM is a simulation model, of the “bottom-up” type, i.e. explaining energy consumptions and CO2 emissions from, as far as possible, activity variables expressed in physical units, containing a detailed representation of emission sources and the main determining factors of the evolution of energy demand and the various types of emissions.

This methodological option is based on the observation that there do not exist simple and homogenous relationships between energy consumptions and macroeconomic variables expressed in monetary units.

The model, which includes a techno-economic data base on the energy consumption and emission reduction measures, is used in particular for:

- the construction of a *reference scenario* (business as usual), representing the most probable future evolution in the absence of any new emission reduction policy;
- evaluating economic emission reduction potentials;
- constructing emission *reduction scenarios*, based on the reduction measures with a marginal cost below a given ceiling;
- constructing *cost curves*, providing either the marginal or the total cost as a function of the level of emission or energy consumption reduction;
- assessing the impact of existing or draft legislations on energy consumptions, emission levels and costs.

The reference scenario is calculated from energy consumptions of a reference year (after climate correction), as well as from assumptions on the evolution of activity variables, specific energy consumptions and market shares of the different fuels.

<u>Industry</u> is represented by about a hundred activity variables (pig iron production, oxygen steel production, ethylene production, clinker production, flat glass production…). The large energy consumption branches are modelled in more detailed than the others. For example, iron & steel production is taken into account per workshop (agglomeration, blast furnace, oxygen steel production…) ; for the chemical industry about twenty basic products are distinguished.

A far as the <u>residential sector</u> is concerned, one distinguishes between existing and new houses, existing and new apartments (electric and non electric heated), domestic water heating and 10 specific uses of electricity (cooking, refrigerators, washing machines, dryers…). The heat load is estimated using a separate module, from a typology of the building stock composed of 14 type-dwellings, of which the dimensioning and the thermal characteristics are entirely defined. In this module, the energy consumptions are calculated using the performances of 15 heat production, distribution or emission systems.

In the tertiary sector, about 30 sub-sectors are grouped into 8 categories, and 5 energy uses are distinguished (heating, ventilation, cooling, lighting and other electric uses). The activity variable is the floor area of buildings.

In the transportation sector, one distinguishes between road transportation of persons, road transportation of goods, rail transportation and inland water transportation. For road transportation, the modelling is carried out in a separate module allowing to calculate emission levels as a function of the average specific energy consumptions of vehicles at the time of their first use and taking into account (European) regulations on polluting emissions applicable at that time.

The emission reduction potentials are calculated in the following way. For each sector, the energy consumptions are divided by use of energy (heating, fans, compressors, cooling, lighting…). For each emission source, the reduction measures are identified, as a function of the use of energy, and costs and performances are evaluated, as well as the technical potential of these measures. By measure, by sector, by energy use and by year, the model calculates the cost per tonne of CO2 as the sum of the annualised investment cost and the operating costs, minus the value of the energy saving achieved. The latter is a function of the energy carrier, the sector, the year and a possible tax.

For CO2, about a hundred measures are taken into account in the model, which may be specific to one or more sectors, to one or more energy uses or generic. These measures can be classified in the following categories: energy saving, cogeneration, renewable energy and energy substitution.

The 'economic' emission reduction potential is defined as the fraction of the technical potential with a marginal cost below a given ceiling (in €/t CO2). In practice, it can be observed that the price of equipments, their utilisation rate, the installation and maintenance costs, as well as the emission reduction rate vary from one particular site or application to another. For this reason, the model takes into account a dispersion around the average cost of each measure, assuming a normal probability distribution. This prevents the economic potential of a particular measure to unrealistically jump from 0% to 100% when its cost decreases from just above the marginal cost ceiling to just under that ceiling, or vice versa.

Reference scenario

The table below shows the evolution of CO2 emissions per aggregate sector for the reference scenario for the *Electricity sector* variant, where emissions of the centralised electricity production are ascribed to the electric sector.

Electricity sector variant*

BELGIUM	**CO2 emissions (Mt)**			**Evolution**		
	1990	1997**	2010	90-97	97-10	90-10
			Ref. sc.		Ref. sc.	Ref. sc.
Energy sector (without autopr.)	27,9	29,1	37,3	4%	28%	34%
Industry	42,2	41,4	47,4	-2%	15%	12%
of which process emissions	*8,6*	*12,5*	*13,7*	*46%*	*10%*	*60%*
Transportation	19,8	22,0	25,7	11%	17%	30%
Domestic and équivalent	27,6	34,1	35,3	24%	3%	28%
Total	**117,4**	**126,5**	**145,7**	**8%**	**15%**	**24%**

* *Emissions of the electricity sector ascribed to the electricity sector*
*** Climate corrected*

The figures for 1997, used as base year for the projection, are corrected so as to reflect an average climate. This climate correction increases the consumption of the residential sector by 7.8% and that of the tertiary sector by 5.6% ('Domestic and equivalent' sector). The year 1990 is not corrected, for it is the reference year of the Kyoto protocol, which does not foresee a climate correction.

In this table, the energy sector represents about a third of the total emissions. It essentially concerns the electricity production sector.

In the following table, the emissions of the electricity production sector are ascribed to the various final consumption sectors, as well as to the net export of electricity (*Final consumption* variant). Hence they are accounted as indirect emissions. The emission factor of the electric kWh used for this is the average emission factor of electricity production for the corresponding year.

The target of the Kyoto protocol for Belgium is an emission reduction of 7.5% in 2010[3] compared with 1990 for the total anthropogenic emissions of CO2, CH4, N2O, PFCs, HFCs and SF6, expressed in t of CO2-eq.

[3] More precisely, for the average over period 2008-2012, which allows a smoothening of the climatic variation.

Final consumption variant*

BELGIUM	**CO2 emissions (Mt)**			**Evolution**		
	1990	1997**	2010	90-97	97-10	90-10
			Ref. sc.		Ref. sc.	Ref. sc.
Energy sector (without autopr.)	6,8	7,8	8,4	15%	7%	24%
Industry	52,2	52,8	63,9	1%	21%	23%
of which process emissions	*8,6*	*12,5*	*13,7*	*46%*	*10%*	*60%*
Transportation	20,2	22,4	26,3	11%	17%	30%
Domestic and équivalent	36,9	44,9	49,5	22%	10%	34%
Net export of electricity	1,4	-1,3	-2,3	-193%	75%	-263%
Total	**117,4**	**126,5**	**145,7**	**8%**	**15%**	**24%**

** Emissions of the electricity sector ascribed to the final consumption sectors*
*** Climate corrected*

If one assumes that the reduction rate is applied to CO_2 only, this would imply a CO_2 emission level of 108.6 Mt CO_2 in 2010. But the reference scenario shows an increase in emissions of 24% between 1990 and 2010. Hence there is a gap of 145.4 – 108.6 = 36.8 Mt CO_2, i.e. 25% of the emissions of the reference scenario in 2010.

The following table shows a synthesis of the reference scenario for all greenhouse gases (GHG) concerned by the Kyoto protocol. Therefore it includes, besides CO_2, CH_4 and N_2O, also the fluorine containing gases HFCs, PFCs and SF_6.

In 2010, CO_2 represents over 83% of the total emissions, and CH_4 and N_2O together 14%. As to the emissions of the fluorine gases, which were still practically not existing in 1995, they are strongly increasing and could reach about 2% of the total.

Overall, the CH_4 emissions decrease by 26% over the period 90-2010, while the N_2O emissions rise by 18% over the same period. The decrease in methane emissions is essentially due to the reduction in emissions of waste dumps.

The results obtained show that in the reference scenario, corresponding to the expected evolution of CO_2, CH_4 and N_2O emissions in the absence of any new emission reduction policy, the emissions of the six gases, expressed in t CO_2-equivalent, increase by 21% between 1990 and 2010. The gap to be filled in order to satisfy the Kyoto target is 41.2 Mt CO_2-eq, i.e. 24% of the emissions of the reference scenario in 2010.

It should be noted that there remains a significant uncertainty on the emission levels, especially for the non CO_2 gases. This uncertainty mainly concerns the emission factors, in particular in agriculture, and their future evolution.

BELGIUM - OVERALL EMISSIONS OF THE "KYOTO" GREENHOUS GASES, IN CO2-EQ
Reference scenario

(kt CO2-eq)	1990 (*)		2010		90-01 evol.
CO2					
Combustion	108.842	*75,6%*	132.015	*75,7%*	21%
Process emissions	8.553	*5,9%*	13.719	*7,9%*	60%
TOTAL	**117.395**	***81,5%***	**145.734**	***83,5%***	**24%**
CH4					
Energy	1.264	*0,9%*	1.101	*0,6%*	-13%
Combustion	311	*0,2%*	315	*0,2%*	1%
Natural gas grids	954	*0,7%*	786	*0,5%*	-18%
Industrial processes	37	*0,0%*	21	*0,0%*	-44%
Waste treatment	4.551	*3,2%*	1.612	*0,9%*	-65%
Agriculture	8.252	*5,7%*	7.700	*4,4%*	-7%
Enteric fermentation	4.855	*3,4%*	4.370	*2,5%*	-10%
Manure storage	3.397	*2,4%*	3.330	*1,9%*	-2%
TOTAL	**14.104**	***9,8%***	**10.434**	***6,0%***	**-26%**
N2O					
Energy	994	*0,7%*	1.696	*1,0%*	71%
Stationary combustion	711	*0,5%*	791	*0,5%*	11%
Transport	283	*0,2%*	905	*0,5%*	220%
Nitric acid production	3.057	*2,1%*	4.423	*2,5%*	45%
Agriculture	7.093	*4,9%*	6.552	*3,8%*	-8%
Emissions from soils	4.874	*3,4%*	4.565	*2,6%*	-6%
Manure storage	2.220	*1,5%*	1.987	*1,1%*	-10%
Forests	729	*0,5%*	729	*0,4%*	0%
Anesthesia	222	*0,2%*	222	*0,1%*	0%
Waste water treatment	0	*0,0%*	662	*0,4%*	
TOTAL	**12.096**	***8,4%***	**14.284**	***8,2%***	**18%**
HFCs, PFCs AND SF6 (**)	**442**	***0,3%***	**4.000**	***2,3%***	**805%**
GENERAL TOTAL	**144.037**	***100,0%***	**174.452**	***100,0%***	**21%**

(*) 1995 in the case of HFCs, PFCs and SF6.
(**) Preliminary estimate

The Kyoto target for the six greenhouse gases CO2, CH4, PFCs, HFCs and SF6, to reduce emissions by 7.5% in 2010 in comparison with 1990 implies an emission level of 133.2 Mt CO2-eq in 2010.

But the reference scenario shows an increase in emissions of 21% between 1990 and 2010. The gap to be filled is 174.4 – 133.2 = 41.2 Mt éq-CO2, i.e. 24% of the emissions of the reference scenario in 2010.

Reduction potential

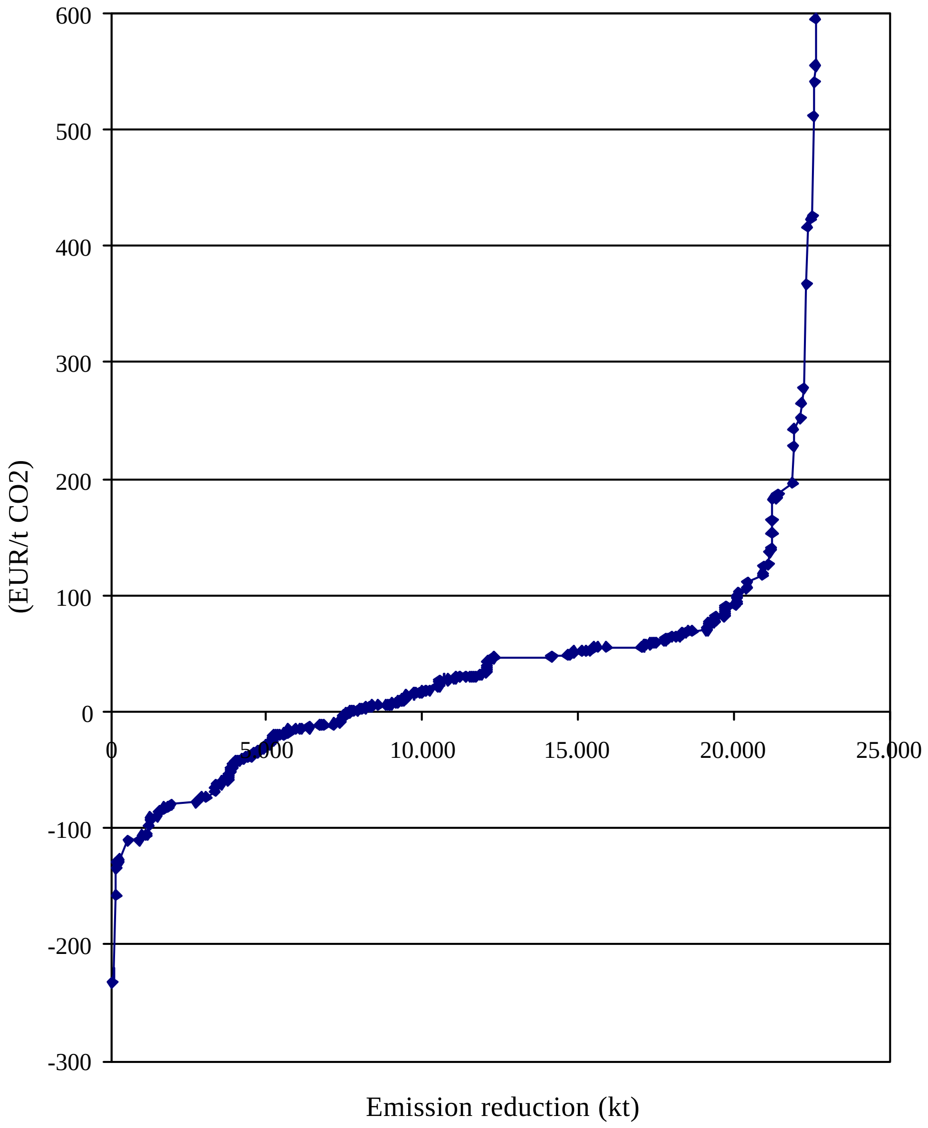
The emission reduction potential (from the reference scenario) has been evaluated in detail for CO_2, for all emission sources outside the transportation sector. This potential is illustrated by the marginal cost curve on the figure below[4].

Marginal reduction cost of CO2 emissions in 2010

(from the reference scenario)

Belgium - ALL SECTOR (except transportation)

Depreciation rates 10-15-30%



[4] It should be noted that such a curve remains approximate, as it does not take into account the dispersion on the cost of reduction measures that has been introduced in the model. For this reason, the economic potentials that can be read on the curve only imperfectly correspond to those of the tables.

If the Kyoto target were to be applied to CO2 only, the figures mentioned above for the reference scenario and the evaluation of the reduction potential give the following situation:

CO2 emissions in 1990 :	117.4 Mt CO2	100%
1990 emissions minus 7,5% (Kyoto target)	108.6 Mt CO2	92.5%
2010 emissions in the reference scenario	145.7 Mt CO2	124%
Required reduction for the Kyoto target (from the reference scenario):	37.1 Mt CO2	100%
Potential of measures (*outside transportation*) :		
Technical potential	22.1 Mt CO2	60%
Contribution of measures with negative cost	9.2 Mt CO2	25%
Contribution of measures < 14 €$_{00}$/t CO2[5]	10.9 Mt CO2	29%

The main options for filling the gap are the following:

- an increased substitution of natural gas in the residential and tertiary sectors;
- measures in the transportation sector;
- the impact on activity variables (lowering of certain production levels, of mobility…);
- a more than proportionate reduction of the emissions of non-CO2 greenhouse gases;
- the use of flexibility mechanisms foreseen in the Kyoto protocol (emissions trading, joint implementation, clean development mechanisms).

The overall potential of emission reduction measures for CH4 and N2O has not been quantified, for two reasons. First, it is difficult to give a 'technical' potential for agriculture, the main emission source, because of the uncertainty remaining on key parameters such as the contribution of modifications of animal feeding, the possible size of livestock reduction, the type of treatment that will be chosen for eliminating excess manure, and the duration of manure storage.

Second, the measures allowing to reduce the emissions of CH4 and N2O of agriculture are generally motivated first of all by the reduction of other pollutions (such as the concentration of nitrates in aquifers and ammonia emissions), so that it is difficult to evaluate the cost of measures to be ascribed to the sole reduction of CH4 and N2O, and so to determine an 'economic' potential for these gases.

However, an estimate can be made of the potential for the main other emission source, the production of nitric acid, for which several catalytic N2O emission reduction processes are presently being developed or demonstrated. Tests carried out on real sites show that a reduction efficiency in the order of 80% can be achieved. If the results obtained can be confirmed and if this technique can be applied to the whole Belgian capacity until 2010, the corresponding potential would, on the basis of the emissions in our reference scenario, be of about 3.5 Mt CO2. Depending on the technique used, the cost should not exceed 1 to 3 €/t CO2.

[5] 14 €$_{00}$ represents the level of the CO2 tax proposed in the National Climate Plan (11,5 €$_{90}$).

The results above should not be considered as definitive. They derive from a large number of data and hypotheses, which are based on the best available information, but on which often remains a significant degree of uncertainty and which could have to be modified in the future.

Beyond the results presented in this report, the EPM model is above all a tool allowing to test hypotheses, and, as such, an instrument of dialogue with the actors concerned (public authorities, industrial sectors…).

In the framework of the project, ECONOTEC has, during the year 2001, collaborated with the Federal Planning Bureau on a coupling of the EPM model with the HERMES macro-sectoral model. This study has allowed the construction of CO2 emission scenarios where the macroeconomic impact of the emission potential estimated by the EPM model is taken into account. The results of this analysis have been used in the third Belgian 'National communication' [6] and in the National Climate Plan 2002-2012.

Besides, the model has also been used in the framework of the preparation of the 'Air Plan' of the Walloon Region.

[6] In the framework of the United Nations Framework Convention on Climate Change.