GREENHOUSE GAS EMISSIONS REDUCTION AND MATERIAL FLOWS

Final Report Summary

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Abstract

Ongoing climate policies intend to promote energy efficiency within all the different activity sectors. Domestic sector is one of those sectors where improvement of energy use efficiency is a major goal of the policies, including energy equipment efficiency improvement, better thermal insulation of buildings,…

A priori it seems however interesting to extend at least the reflection around consumer behaviour to consumer goods in general. Measures aiming at tackling the consumer side with respect to products should promote those that generate the lowest levels of greenhouse gas (GHG) emissions throughout the life cycle, namely from cradle to grave. Such a reflection necessarily implies to take into account technology improvement within the production system.

The project "Greenhouse gas emissions reduction and material flows", undertaken in the framework of the Action Plan for Sustainable Development (phase I) of the "Global Change and Sustainable Development" programme of the OSTC, aims at developing such a reflection through a quantitative way. The project has been carried out by Institut Wallon, Vito and IDD, being Institut Wallon the co-ordinator of the project.

In order to illustrate and quantify the impact of such an approach, we have analysed three product categories and their product system[1] : housing, beverage packaging and livestock products.

The aim is to evaluate the life cycle GHG emissions related to those three product systems as well as the ways to reduce these emissions both through measures addressed to the consumer and through measures implemented within the production system.

This document synthesises the results of the project. They are described in detail in the final report document (see Nemry F., Theunis J., Bréchet Th., Lopez P.)[2]

[1] The product system comprise the products use, materials manufacturing and transport and treatment of wastes generated after product use.

[2] Nemry F., Theunis J., Bréchet Th., Lopez P., 2001, Greenhouse gas emissions reduction and Material flows, Final report, For the OSTC.

1. The objectives of the study

In the framework of the Kyoto Protocol, Belgium, as part of the European Union, has committed itself to reduce its annual greenhouse gas emissions by 7.5% in the period 2008-2012 compared to the 1990-1995 levels.

With regard to the substantial carbon dioxide (CO_2) emissions in Belgium (more than 80% of total GHG emissions), additional improvements in energy efficiency have to be pursued by all the activities sector. Due to the addition of other greenhouse gases (CH_4, N_2O, SF_6, HFC's and PFC's) in the Protocol, efforts should also be extended at the level of the industrial processes, products consumption and agriculture. Besides this, the reports from the Intergovernmental Panel on Climate Change (IPCC) (especially its recent Third Assessment Report) show the need to develop strategies for the long term to be continued beyond 2010.

As a result, considerable work is required to develop new options for GHG emissions mitigation as well as effective instruments that create synergies between the different actors involved. The project « Greenhouse gas emissions reduction and material flows », undertaken by IW, Vito and IDD and co-ordinated by IW, aims at identifying supplementary long-term options of GHG emissions reduction.

One main observation was a starting point for the project: Demand for products by households represents a demand for various materials. The resulting material flows on their turn represent energy flows and greenhouses gases emissions as materials are subject to successive transformations and transportation. However, except for final energy consumption, the influence of consumer choices is not really taken into account in present climate change policies.

The present study aims at answering three basic questions around the consumer role in environmental impacts through their consumer patterns simultaneously with a consideration of production side with its technological evolution, including environmental performance improvements:

1. What is the impact of consumer choices on GHG emissions, namely through the product-related life cycle emissions? Especially what could be the impact of changes in product choices and in materials contained in products?

2. What is the impact of process substitutions on GHG emissions?

3. What could be the contribution of consumer patterns changes to the GHG reduction emissions efforts for the first commitment period of the Kyoto Protocol (2001-2012) but also for the subsequent commitment periods?

The project intended to give first answers to these questions on the basis of three illustrative specific consumption categories: residential housing, livestock products and beverage packaging.

2. Approach and methodology

2.1. The approach

The analytical approach that has been followed is an end-use approach which means that the Belgian final demand for the three product categories (or for their function) was a starting element to be analysed in the project.

Moreover due to the “indirect” effect of consumer choices on resource consumption and environmental impacts, a life cycle approach imposed itself : this means that the environmental impacts to be considered in relation to the demand for defined products are those as produced from cradle to grave (from the extraction of raw materials to waste treatment).

At the same time, while the consumer demand was the main driving force considered it was important to evaluate both life cycle environmental impacts and potentials to reduce them, taking into account possible technological improvements within the upstream production system and downstream waste treatment system. For this reason, a dynamic approach has been adopted in order to take into account the evolution of technologies and consumption changes.

Finally, a double analytical work has been performed in order to meet a double concern, namely :

- to give an exhaustive picture of the three product systems, from the demand side to the production side and the waste treatment side, in order to draw the most realistic conclusions,

- to develop consistent insights on GHG emissions evolution and potentials for emissions reduction, including consistent cost evaluations,

This double analytical work has incorporated a detailed description of the product systems on one side and the application of MARKAL for two of the three product groups on the other side. Both approaches are mutually supporting.

2.2. The methodology

In order to implement this original approach, different steps were followed as explained below :

1. The demand for the three product categories has been analysed : based on various data sources (mainly statistical data), the existing demands for products and their recent evolution have been depicted and analysed. Then econometry has been used by IDD to develop scenarios for the future trends.

2. Then the main materials involved in the product systems were identified. The different material flows, namely imports, exports, domestic production and consumption (including, in some cases, flows of waste materials) were quantified essentially on the basis of statistical data from industrial federations. This part of the study allowed evaluating the importance of the domestic production compared to domestic consumption, especially consumption that could be attributed to the products studied.

3. Another step was the analysis of production processes as currently existing but also as potentially developing in the future. The GHG emissions and costs of the technologies were analysed. It is to be noted that this sub-task was more or less focused on the Belgian production system depending on the importance of the domestic production compared to the national consumption.

4. The previous steps allowed calculating the life cycle emissions for the different products, both at the level of the product and at the level of their Belgian demand.

5. The last step has consisted in the evaluation of GHG emission potential reductions at the different levels of the product life cycles. This evaluation has been performed both with simplified scenarios and MARKAL applications. The latter allowed providing a dynamic, integrated and economic evaluation of the potential.

2.3. Three illustrative cases

The application of this approach and methodology for the three selected product categories is justified by the fact that all three products represent an important part of the day-to-day consumption. They are also complementary with respect to the need they relate to, the materials they involve and the GHG they emit (see Table 1) and by the fact that these product categories offer possibilities for reducing the GHG emissions during their life cycle. This selection also covers different sectors. Wood as a building material makes it possible to include the carbon sinks issue in the analysis. Finally, livestock allows including non-CO_2 GHG emissions in the analysis.

Partner	*IDD*	*Vito*	*IW*
Product category	**Livestock products**	**Packaging**	**Residential housing**
Products	Meat	Beverage packaging	Single family houses
“Materials” involved	animals, fertilizers, fodder…	Plastic, paper, glass, steel, aluminium	Steel, cement, concrete, glass, bricks, wood
Main GHG emitted	CH_4, N_2O, CO_2	CO_2	CO_2

Table 1 : Main features of the product categories studied and the author of their evaluation

2.4. MARKAL as applied to material flows

MARKAL (MARKet Allocation) is a Linear Programming model developed in the framework of the "Energy Technology Systems Analysis Programme" (ETSAP) of the International Energy Agency (IEA). It has been developed and used extensively to model the energy system in numerous OECD countries since 20 years, including Belgium. In Belgium, it has been used by KULeuven and Vito until present. In this usual application, the model selects the least cost combination of processes and flows that satisfies the exogenous demand for energy services over a given time period (typically several decades) under given exogenous constraints, starting from an existing exogenous transformation system and predefined alternative technological options. It calculates the resulting total system cost, total or specific emissions, energy flows, process activities, and shadow prices for produced goods.

MARKAL optimises the system over the entire time period and the entire system. It supposes rational decision making based on full foresight and full transparency.

Its high flexibility with regard to the description of technology, sectors and environmental impacts allowed developing a new MARKAL version to include an explicit description and modelling of material and product flows, and a more detailed description of competing technologies (including waste treatment technologies), materials and products. This was made for the first time in the framework of the MATTER[3] project (see ECN, The Netherlands). In this extensive and long term project, a global and consistent model was developed to represent an integrated energy and materials system for Western Europe.

Such a development is part of the current project. However, adaptations have been made to take into account some specificity of the present project with regard to geographic boundaries, the higher emphasis on product demand and the specific product categories envisaged. These adaptations resulted in the development of two separate models for residential housing and for beverage packaging. Then scenarios on GHG emissions evolution were carried out.

3. Modelling demand and macro-sectoral framework

IDD was in charge of the determination of demand for the three chains considered in the project. An econometric model was developed for private consumption in which products are defined in physical terms inside a comprehensive socio-economic model describing household's consumption patterns. This model is called CORELLI. The main features of the CORELLI model are the following :

- It is an econometric model : the purpose of the model is to forecast the demand up to 2010, and econometrics is a technical way to provide reliable results, as far as the timespan is not too long. The demand equation for each category of product is estimated on the longest sample available.
- It is a bottom-up model : instead of disaggregating the overall consumption with a DLES, an AIDS or a Translog system, the model aggregates primary demand functions; these functions are estimated simultaneously in order to take care of crossed correlations.
- It is a model in which data can be expressed both in : this is the case for the products considered in the chains "meat products" and "packaging for beverages". The bottom-up structure of the model allows aggregating these two kinds of data.

Table 2 shows the consumption categories considered inside the CORELLI model. The model is able to provide forecasts up to 2010 and to evaluate the impacts of fiscal policies, both on the whole consumption patterns and on the most detailed categories.

As far as dwelling is considered, another model has been built. The demand considered for this chain is defined as the demand for new single family houses, expressed in m^2. The LOCATELLI model is a stock-flow model which describes the park of houses each year, depending on the rate of construction, demolition and renovation. The size of new houses is also endogenous. The model is characterised by the introduction of both socio-economic behaviours (validated with econometrics) and demographic components. Econometrics allowed quantifying the impact of real income, long term interest rates or ABEX index on the demand for dwelling. The demographic part of the model is considered from the decomposition of the total Belgian population in several types of households (singles, with or without children, etc…) ; each household is characterised by its preference towards one kind of housing. The evolution of these demographic components influences the demand for single family houses. LOCATELLI allows acquiring forecasts up to 2020 and the evaluation of many alternative scenarios.

Overall consumption	of which beverages (in liters per capita)	of which meat products (in kg per capita)
Food, beverages and tobacco	Carbonated waters	Beef
Food	Non-carbonated waters	Veal
Bread and cereals	Soft drinks	Pork
Meat	Milk and milk drinks	Sheep
Fish	Fruit juices	Horse
Milk, cheese and eggs	Beers	Chicken
Oil and fat	Wine and alcohols	Other poultry
Fruits and vegetables		Rabbit
Potatoes and tubers		Edible offals
Sugar		
Coffee, tea and cacao		
Others, incl. tins		
Non alcoholic beverages		
Alcoholic beverages		
Tobacco		
Other goods and services		

Table 2: Consumption categories in the CORELLI model

[3] See http://www.ecn.nl/unit_bs/etsap/markal/matter/main.html

4. Residential housing system

Buildings, especially residential buildings, play a major role in satisfying human needs: the primary function, i.e. sheltering people is primordial for the satisfaction of other needs (heating, private life, leisure, aesthetic, space, health…). On the other side, building construction, which implies the use of different materials like cement, steel, glass, bricks, plastic…, is an important sector from a materials consumption point of view, so involving high levels of energy consumption. The potential role of wood in building poses also the carbon sink problem, which is an important issue in the Kyoto Protocol. Waste is also a significant issue regarding building materials.

The function studied is the "residential housing". The analysis focuses on the functional group "single family houses" (SFH). This choice is justified by its quantitative significance (single family houses represent more than 80% of the total housings in Belgium) but also by the higher influence of individual consumer choices compared to multi-family houses.

4.1. Demand and product description

Housing is intensively described by statistical data (INS, National Statistic Institute). Every year about 20.000 new houses are built. The exact amount depends on different factors and there is no clear trend during the last years. On the opposite, there is an obvious increasing trend of total surface built per house. Besides new construction, renovation plays an important place in the building sector. Among all renovations with transformation, renovation with surface increases account for more than 80%.

Both new construction and renovation (especially with surface increases) represent significant material consumption and hence life cycle energy consumption and GHG emissions. Taking into account the importance of both options and the fact that they represent potential mutual substitutions, the analysis focused on them.

With regard to architectural types both with respect to shape and to material involved, the huge diversity within the Belgian market couldn't obviously be taken into account. Consultation of experts from the sector (architects and entrepreneurs), the analysis of technical documentation combined with observation lead to a build up of a simplified market representation.

- A limited set of houses differing in the materials used has been selected, going from so-called "conventional houses" (concrete/brick or brick) to wooden houses (with brick or wood facing), also including intermediary cases like expanded clay or cellular concrete. All options were estimated to have the same thermal insulation level.
- Based on three actual recent new constructions for which precise quantified surveys were provided by architects, extrapolation curves were built in order to represent the different building elements size as a function of total built surface, so allowing to estimate the influence of surface on material consumption and hence life cycle emissions.

4.2. Material flows analysis

The analysis of material flows has been done for the main materials: cement, concrete, bricks, glass, steel, non-ferrous metals, making use of different data sources (industrial federations, statistical data, surveys by IW…). The analysis was somehow hampered by the availability and quality of some data. Some materials are particularly uneasily traced: for instance, this is the case of wood products and intermediary productions of the steel sector.

Nevertheless, the analysis showed that Belgian production of most building materials is relatively important with respect to the domestic demand. However, foreign exchanges are important for wood and reinforcement steel. The weight of consumption related to SFH new construction and renovation in particular is also variable from one material to the other (65% for bricks, 52% for cement and only 3% for glass and 6% for steel).

4.3. Material production processes description

The results of the material flow analysis justified to make an in-depth analysis of industrial processes with respect to the Belgian situation. This part of the analysis has described the main production routes in the Belgian industry, the fundamental processes and their relevant characteristics. Then alternatives for production and energy consumption of the Belgian industry existing world-wide are analysed. New and emerging technologies were also identified.

4.4. Life cycle emissions

The material intensity and the indirect GHG emissions[4] have been performed for each of the houses cases based on the previous GHG emissions estimations associated to the materials use and manufacturing. This was done through a systematic calculation for each building element (foundations, walls, floors, roof, windows,…).

Life cycle GHG emissions as calculated for different types of houses (200 m^2 total surface) are represented in Figure 1.

It shows that the construction of new conventional houses (brick and concrete) implies indirect GHG emissions ranging from 40 to 50 t CO_2 depending on the construction of a cellar. This represents from 7% to 14% of the direct emissions (house heating) during the whole life of the house. This percentage depends on the lifetime of the building and on the fuel used for heating (natural gas or oil).

The figure also shows the emissions reduction potential that exist at the level of individual houses, especially when shifting from conventional houses to wood construction and from new construction to renovation.

It is also to be noted that according to our estimations, the GHG indirect emissions increase by 38% when surface increases by 50%.

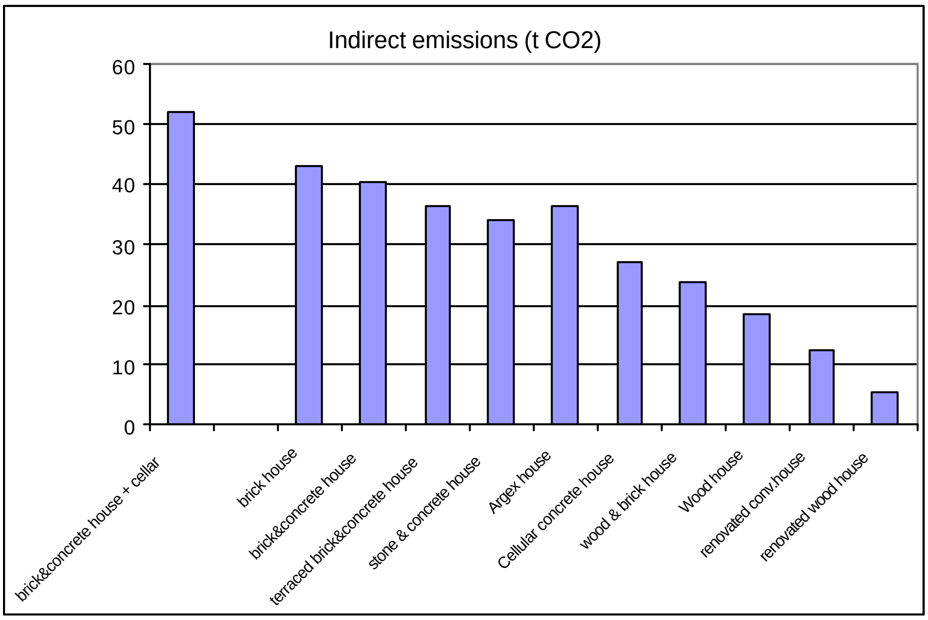

Figure 1 : Comparison of indirect GHG emissions for different houses (living surface : 200 m^2)

[4] We use the term "indirect emission" instead of "lifecycle emissions" because the analysis didn't calculate explicitly the GHG emissions due to heating (thermal insulation was the same for all buildings). It has also to be noted that we use indifferently the terms "CO2 emissions and GHG emissions" because CO2 is the main GHG emitted by this product system.

Estimating the related indirect emissions at the level of Belgian demand for new construction and renovation requires to have an estimation of the present sharing of different types of houses in the market. Due to the lack of statistical data, we had to make own estimations based on expert judgements and observations. We have considered that about 80% of new houses are conventional houses, that 16% are intermediary cases (expanded clay or cellular concrete) and that 4% are wooden houses. Given this share and also taking into account renovation (mostly of conventional type) the total indirect GHG emissions can be estimated to 1750 kt CO_2.

4.5. Technical emissions reduction potential

In a Kyoto perspective it is interesting to estimate the potential evolution of indirect GHG emissions from new SFH constructions and renovations until 2010. The base case scenario for housing demand has been carried out by IDD with the Locatelli model. Two alternative GHG emissions curves have been calculated with this projection, assuming no technology changes within the production system : the first one assumes a constant share of houses types (as estimated for now), the second assumes an increasing contribution of intermediary houses types and wooden houses (30% and 25% respectively).

The resulting two GHG scenarios are represented in Figure 2.

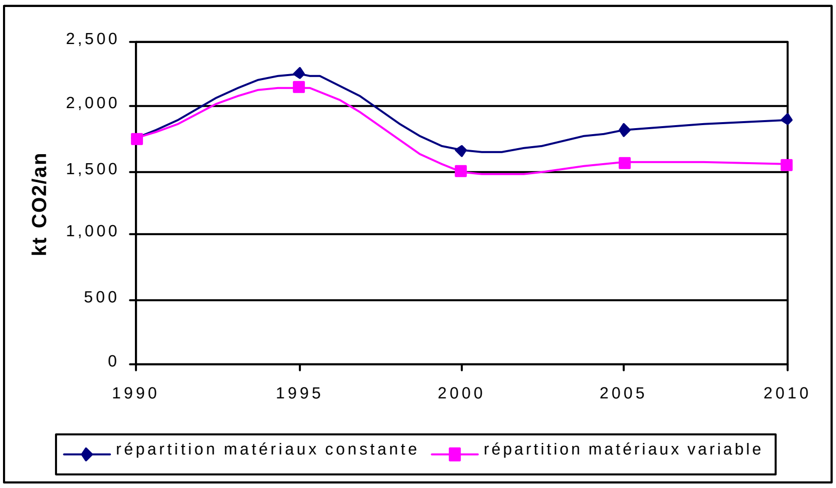

Figure 2 : Indirect CO2 emissions scenarios

The upper curve represents the first scenario and the lower the second. In the first case, GHG emissions could achieve 1900 kton in 2010 while they would attain 1550 kton in the second case, which represents a decrease of 11% compared to the BAU scenario.

These results provide an order-of-magnitude of the emissions reduction potential from built or renovated houses substitutions. This potentials are, however, theoretical potentials as they suppose that no technological evolution will occur within the building materials fabrication system. Nevertheless, it is opportune to evaluate the costs of eventual reductions.

A more integrated analysis has been carried out from the development of a MARKAL model specific to the housing system. This model has represented the different building materials fabrication processes as well as housing construction and renovation for different housing types. The exogenous demand for these houses (construction and renovation), is again based on the reference results of the model LOCATELLI developed by IDD.

Different scenarios have been built in this study taking into account the different demand hypothesis. They are described in the table bellow.

Scenario	***Demand taken into account***	*Constraint on the CO_2 emissions*	***Other constraints***
BASE	*Residual demand*	*None*	-
BASEHOUS	*Residual demand + housing demand*	*None*	-
KYOTO	*Residual demand*	*Base level : emissions from residual demand in 1990* *2010 : -7.5%* compared to base emissions *2030 : -15%* compared to base emissions	-
KYOTOH	*Residual demand + housing demand*	*Base level : emissions from residual demand + housing demand in 1990* *2010 : -7.5%* compared to base emissions *2030 : -15%* compared to base emissions.	-
KYOTOP			*Contribution of wooden houses is imposed*

Table 3 : Scenarios for housing system

Results from this model indicate that for the system studied, shift in technologies as a CO2 mitigation measure is more cost effective than shift in product types from more emitting products to less emitting products: In both scenarios KYOTO and KYOTOH, where the model chooses freely the technologies that allow the minimisation of the total cost, the same technology evolutions are observed. For the KYOTOH scenario, we observe that the additional emission reduction to be achieved compared with the KYOTO scenario is accomplished through additional technology shifts and that no change is made on the product side.

Next table gives the resulting costs for greenhouse gas emissions reduction for the three scenarios. They indicate that the cost increases slightly when reduction efforts cover the highest volume of emissions. When a constraint is put on the share of construction types, the cost is higher (128 Euro/t CO2 instead of 37 Euro/t CO2) than without any constraints.

Scenario	**Reduction cost (Euro/t CO2)**
KYOTO	28
KYOTOH	37
KYOTOP	128

Table 4 : Cost for CO2 emissions reduction for housing system
and residual demand of building materials

This is due to the higher estimated price of “low emitting” houses (stone, cellular concrete, brick&wood and wood houses) compared with the price of the more conventional houses (especially brick&concrete house). Stone houses are about twice more expensive than conventional houses. Average price of cellular concrete houses appear to be 10% more expensive than conventional houses and brick&wood houses as well as full wooden houses are 20% more expensive. These overcosts are, comparatively to the overcosts involved in technological changes, higher and hence the model chooses this last emissions reduction measure in priority.

The result itself is however questioned by three major facts :

- The experience gained with this analysis indicated a substantial uncertainty on costs of technologies found in literature. Although these costs were adjusted in order to better reflect the market prices and better reproduce the comparative price of the different houses considered, there remains a high uncertainty on the costs of technology shifts and the costs of product shifts.

- Results have been obtained from a choice of the system boundaries. We can not disregard the possibility that another choice of the system boundaries would have led to the same conclusions. However, it was very difficult to check this possibility within the scope of this project.

- Then costs data assumed do not take into account a possible influence of the market development on technology costs.

Further analysis of the different uncertainties would be useful. However, a proper treatment of uncertainties is not straightforward with MARKAL and would require an intensive work which is out of the scope of this study.

5. Livestock products system

The function retained in this system for breeding products is defined as the quantity (in kg) of meat products per capita and per year. The demand for the nine meat products comes from the CORELLI model. A chain analysis is realized for the main categories : beef and veal, pork, poultry and sheep.

The indirect greenhouse gas emissions embodied in the production processes (considered from a LCA approach) have been calculated at each step of the chain. These steps are the following : production and use of fertilizers, production and use of pesticides, feed production, animal production (breeding), slaughtering, transport (between production and slaughtering and between slaughtering and consumption). The GHG considered are CO2, CH4 and N2O. The major GHG are CH4 and N2O. These gas emissions have been aggregated with their Global Warming Potential over 100 years.

The table below displays the indirect emission coefficient for the three gas considered as a whole and they are expressed in CO2-equivalent. The first column gives the emissions per kg of meat product and the second column gives the repartition between the three gases considered. CH4 is the main contributor for beef, but also for pork whereas N2O is mainly concerned in the sheep production. Poultry production is mainly responsible for CO2 emissions. The level of emissions is very high for beef and sheep (14 and 18 kg od CO2-eq per kg of meat product) and is low for pork and poultry (2 and 3 kg).

	Beef		Pork		Poultry		Sheep	
CO_2	3,4	23,2%	0,9	24,7%	0,8	37,4%	1,9	9,9%
CH_4	6,3	42,4%	1,7	46,2%	0,7	31,1%	7,6	40,5%
N_2O	5,1	34,5%	1,1	29,1%	0,7	31,5%	9,3	49,6%
Total	14,8	100,0%	3,6	100,0%	2,1	100,0%	18,8	100,0%

Table 5: Indirect GHG emissions : in kg CO2-eq / kg of meat

	Beef		Pork		Poultry		Sheep	
Fertilisers production	2 380	16,1%	442	12,2%	261	12,46%	1 719	9,15%
Feed production	4 669	31,6%	707	19,5%	699	33,38%	2 593	13,80%
Breeding	7 422	50,2%	2 045	56,5%	816	38,96%	14 216	75,67%
Transport	154	1,0%	205	5,7%	151	7,23%	122	0,65%
Slaughtering	14	0,1%	14	0,4%	15	0,74%	13	0,07%
Transport	154	1,0%	205	5,7%	151	7,23%	122	0,65%
Total	14 795		3 620		2 094		18 788	

Table 6: Decomposition of indirect GHG emissions by source (in gr CO2-eq / kg)

The analysis of material flows has provided a calculation of each emissions contribution in the global Belgian GHG emissions, considering imports at each level of the chain. These emissions represent around 4% of the total Belgian GHG emissions.

The baseline scenario considered from the CORELLI model shows that, considering the evolution of the consumption patterns, indirect emissions due to meat consumption should decrease from today till 2010. This is due to a relative preference towards white meats (poultry, veal…) and a very small increase in global meat consumption. Emissions involved in meat consumption achieve around 7,1 Mt CO2-eq in 2000 and they would decrease to 6,1 Mt in 2010.

Finally, the study reveals that consumption patterns can have a significant impact on indirect emissions. A reduction of the beef consumption by 10% compensated by an increase of poultry consumption in order to maintain the global meat consumption unchanged would reduce total GHG emissions by around 0.9 Mt CO2-eq. The mean costs for consumers would be 530 €/tCO2-eq. However, the evaluation of the direct and indirect impacts on sectoral activity reveals that employment would be reduced (around 1,200 jobs on the long term). The imposition of a tax proportional to the content in GHG for each meat must also be considered in order to evaluate the possibilities for substitution among the consumption pattern. For example, a tax of 250 €/tCO2-eq would reduce emissions from meat production by 9% on the long term. This represents 0.5 Mt CO2-eq. Methane would be the main contributor to this reduction.

6. Beverage packaging

In terms of packaging weight beverage packaging represents more than 40 % of the total end use of household packaging in Belgium. This high share is partially caused by the fact that 67 % of all beverage packaging are glass bottles.

6.1. End use demand and packaging options

The projected demand for packaging was derived from the projected demand for beverages provided by the Corelli model (see §3).

All beverages (excluding draught beer) were put into six groups according to their technical packaging requirements and matched with eight types of beverage packaging.

PET bottles are increasingly used for beverage packaging, also for applications from which they were excluded until now because of technical constraints. Reuse PET bottles are actually not used in Belgium. PVC has almost completely disappeared. The use of reuse bottles is declining.

6.2. Analysis of material flows and transformation processes

For most of the materials used for packaging, as well as for intermediates in materials production and for the packaging themselves (whether filled or not), imports and exports are quite important. Large discrepancies can exist between the end use of packaging, the intermediate use of packaging by packers of products and the packaging production. Changes in the Belgian final demand for packaging will have a limited influence on the production of packaging, packaging materials and intermediates in Belgium. Therefore, European standard processes and potential improvement options were analysed.

For treatment of used products on the other hand, two cases have to be distinguished:

- Waste collection, incineration or landfilling, and sorting are essentially local processes.
- Once waste streams have been sorted and can be valorised, they can cross boundaries.

For waste paper and cardboard, steel and aluminium, recycling is integrated in the standard production processes and international markets are well established. For plastics on the other hand recycling technologies are in full development and markets are underdeveloped.

6.3. Scenarios

Two complementary approaches have been used to estimate the greenhouse gas emissions and the emission reduction potential related to the end use of beverage packaging in Belgium:

- a base model (PackBase) based on average emission factors for materials and energy production, and fixed scenarios for changes in packaging use and recycling rates;

- a MARKAL partial optimisation model (PackMark) in which the choice of packaging and recyling rates is optimised on cost basis.

To calculate the potential reduction of greenhouse gas emissions, the PackBase model combines two sets of scenarios.

6.3.1. End use scenarios

Ranging from a stand-still, over moderate to rather drastic changes in choice of packaging: gradual replacement of packaging with higher emission factors (g CO_2 eq/l) with packaging with lower emission factors, taking into account technical and sociological constraints. In most cases it involves an increase of reuse (use of reuse PET wherever possible).

BAU	further decrease in reuse glass, replaced by one-way PET - one-way PET partially replacing cans - beverage cartons and reuse glass for milk products partially replaced by HDPE
FR	no changes in packaging choice
NIR	no increase in reuse - replacement by "best option" (except for ± 5 %)
RU1	increase of reuse (mainly reuse PET) - moderate use of PET and reuse PET for beer - wine and spirits : 90 % glass; 20 % reuse
RU2	more drastic increase of reuse PET - increased use of (reuse) PET for beer - wine and spirits : 85 % glass; 20 % reuse
RU3	maximum reuse (large: 90 %; small: 80 %, exc. wine: 30 %) - wine and spirits : 80 % glass

Table 7: End use scenarios for the PackBase model

6.3.2. Materials production and waste treatment scenarios

The emission factors for the different beverage packaging options (g CO_2-eq/l) change as a result of changes in weights and recycling rates.

FEF (fixed emission factors)	no changes in emission factor
M	decrease in materials use (weight) per packaging type
M+RW	increasing % waste recycling
M+RW+RP	increasing % recycled material in production

Table 8: Materials production and waste treatment scenarios for the PackBase model

In the PackMark model the BAU end use scenario has also been used. In all other scenarios (see Table 9) the possible shifts in end use were confined within specified ranges according to the maximum substitution potential that is considered to be achievable.

BAU	fixed packaging end use
OPT	end use optimisation without greenhouse gas emission limit
RE-15	end use optimisation - greenhouse gas emission limit at 85 % of the level of 2000
RE-30	end use optimisation - greenhouse gas emission limit at 70 % of the level of 2000
RE-MAX	end use optimisation - greenhouse gas emission limit at minimum possible

Table 9: Scenarios for the PackMark model

To take into account the uncertainty on the cost data all scenarios were run also with a decrease in specific packaging costs of 15% for reuse options.

6.3.3. Greenhouse gas emissions and improvement potential

Greenhouse gas emissions per packed liter of beverage are smaller for reuse packaging (glass and PET) than for all one way packaging options except beverage cartons. Greenhouse gas emissions related to materials use (including waste treatment) dominate greenhouse gas emissions during the use phase of the packaging (making, filling, cleaning, transport). They can be reduced significantly through decreases in packaging weight and increased recycling.

Results of the PackBase model are shown in Figure 3. Results of the PackMark model are summarised in Figure 4, which shows changes in end use of beverage packaging in a 15% greenhouse gas emission reduction case, and Figure 5, which shows the costs of emission reduction.

The total greenhouse gas emissions related to the end use of beverage packaging in Belgium can be estimated at 500 - 600 kton. In the absence of measures to reduce greenhouse gas emissions these emissions will increase by 50 to 100 kton.

Although the reduced use of materials per packaging unit (reduced packaging weight) as well as some of the changes that come into effect in a cost optimisation without emission limits, lead to reductions in greenhouse gas emissions, on the whole greenhouse gas emissions increase, because of the increase in beverage consumption and the gradual replacement of reuse packaging by one way PET bottles.

Calculations of the emission reduction potential show a maximum reduction potential of 300 to 350 kton. However, this implies drastic changes in the use of beverage packaging. More realistic estimates show a reduction potential of 250 to 300 kton.

Increased recycling is a cheaper option for greenhouse gas emission reduction, but it has a limited potential. Increased reuse gives significant additional benefits compared to increased recycling only (up to more than 150 kton).

Increasing the use of reuse bottles (mainly PET reuse) seems the most powerful strategy for reducing greenhouse gas emissions related to beverage packaging. However, the actual trend goes in the opposite direction. Only when imposing greenhouse gas emission limits, reuse PET becomes an attractive option.

The influence of some crucial parameters on the emissions and the emission reduction potential was tested. Although total emissions can change by 10%, the influence on the reduction potential is limited.

There is quite some potential for greenhouse gas reduction without additional **cost** compared to the actual situation and compared to a scenario with slight changes in packaging use. Compared to the BAU scenario, the changes in recycling rate and packaging use taking place in the 15% and 30% reduction scenarios, lead to a reduction in packaging cost.

However, when comparing emissions and costs of reduction scenarios to a situation in which packaging use is optimised without emission limits, the average emission reduction cost was estimated at 130 Euro/ton in case of a 15% emission reduction (compared to the 2000 level), and 228 Euro/ton in case of a 30% emission reduction. This result is very sensible to the price difference between one way and reuse packaging options. If the specific costs for reuse are reduced by 15%, the GHG emission reduction costs are reduced by 45% to 55%.

It should be kept in mind that the OPT scenario gives a very drastic view. Most probably, the average packaging cost will not fully reduce to the level of the OPT scenario. Hence, these emission reduction costs should be interpreted as upper limits.

Life cycle greenhouse gas emissions related to the end use of beverage packaging in Belgium represent about 0,3 to 0,4% of the total Belgian greenhouse gas emissions. The calculated emission reduction potential corresponds to 1,1 to 1,4% of the total emission reduction effort that Belgium has to realise in the period 2000 – 2010 (approximately 22 Mton).

The comparison is however not fully correct because a significant part of the life cycle greenhouse gas emissions are related to imported materials or products, and will occur abroad. Hence, a significant part of the emission reduction potential will be realised abroad, and will not help Belgium in reaching its emission reduction targets. Similarly, Belgian production of (packaging) materials for export will contribute to the life cycle greenhouse gas emissions related to the end use of beverage packaging abroad.

It is not clear which part of the emission reduction will be realised in Belgium. Taking into account the large imports of intermediates in material production, materials and packaging itself, and the export of waste materials (see Part III), the share of the "imported" emissions and "exported" emission credits will probably be at least 50 %.

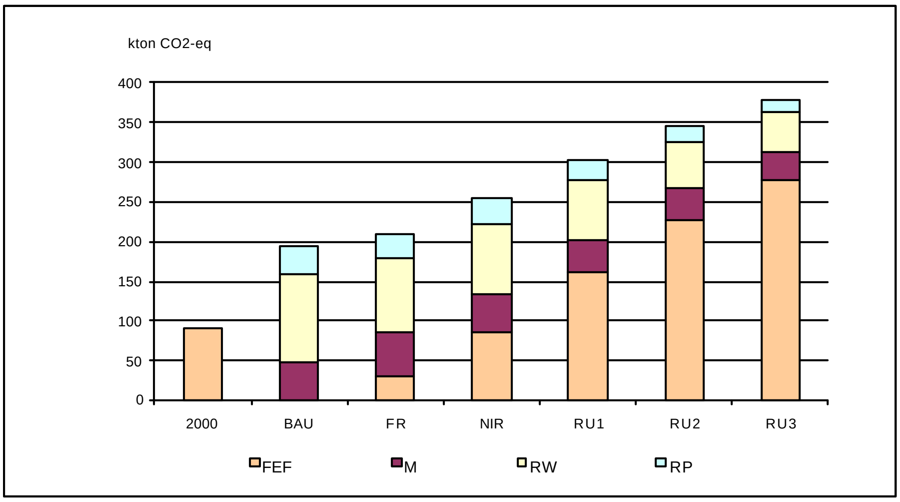

Figure 3: Greenhouse gas emission reduction potential of combined end use scenarios and materials production and waste treatment scenarios

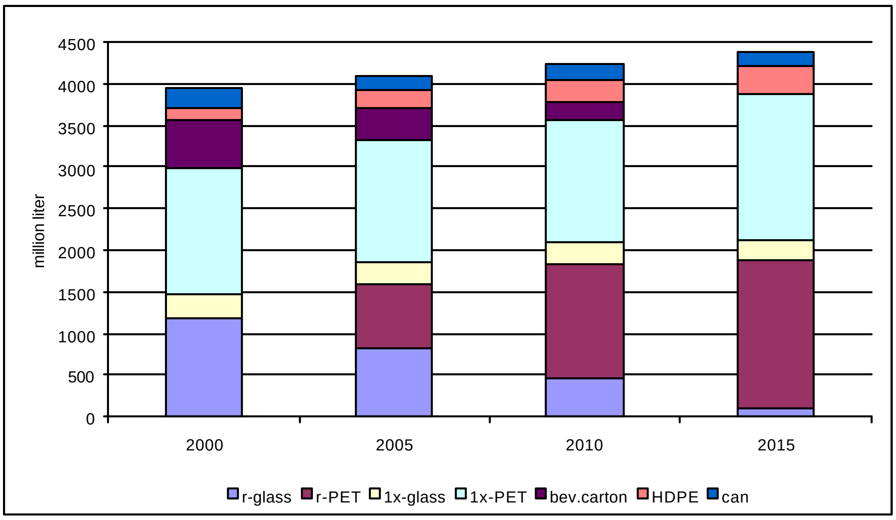

Figure 4: End use of beverage packaging – 15% reduction scenario

[5] both an increase in the use of recycled material in the production of packaging, as an increase in the recycling rate of used packaging
[6] "craddle-to-gate"

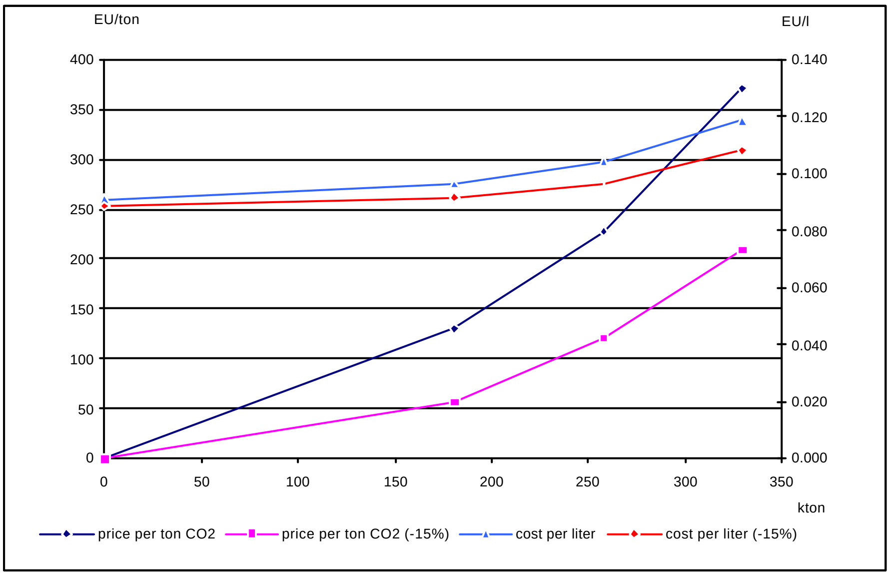

Figure 5: Cost of greenhouse gas emissions reduction (compared to OPT scenario)

7. Conclusions

The approach followed in this project aimed at giving insights in the greenhouse gas (GHG) emissions indirectly induced by the consumption of some product categories (single family houses, meat and beverage packaging). The aim was also to assess the possible contribution of consumer choices (including product substitution) to the reduction of GHG emissions. The assessment has been made taking into account the possible future evolution of the technologies involved in the life cycle of the products considered. Costs analyses were also carried out.

A substantial amount of work has been carried out in order to collect the numerous data needed in this project : these data relate to the different flows of materials involved in the three product systems, the description of technologies, the description of products and the market analysis.

Different methodological developments have also been undertaken in order to achieve the goals of the project :

A consistent modelling of the demand has been carried out for all three product categories : a bottom-up econometric model has been developed for the whole consumption pattern for breeding products and beverages and a stock-flow model has been developed for the housing demand.

While material flows have received very little attention in Belgium up to now, this study has constituted a first attempt to analyse the relevant material flows for the three product systems. The analysis has led to different conclusions for each product system : while foreign trade plays a small role for most building materials, the meat system and especially the beverage packaging system involves significant imports and exports both for intermediary materials and final products.

More fundamentally the ambition to quantify the greenhouse gas reduction potential related to the end use of specific product groups in Belgium has represented an important methodological challenge. An intermediary way between the development of a global and complex models such as the model built in the MATTER MARKAL study and the product-specific LCA approach has been found.

Linking projections on demand with technical improvement options and specific emission factors enabled us to give some insights in the possible impact of policies addressing consumption patterns and their environmental impacts. This macro-level quantification of the emission reduction potential gives relevant additional information in policy discussions, as compared to the results of LCA studies (e.g. in the discussion on reuse and one-way packaging).

To be able to take into account the cost factor, MARKAL models were developed for two of the product categories studied (housing and beverage packaging). MARKAL provides a structured framework for evaluating costs taking into account technical evolutions over a long time period. For the meat system, costs analysis were undertaken on an independent econometric analysis.

In absolute terms, the research has evaluated the life cycle GHG emissions related to three product categories to levels of less than 1% to 4% of the Belgian 1990 GHG emissions. At the same time it has revealed that, in relative terms, product substitutions within each product category may represent significant reductions of the life cycle emissions resulting from the Belgian demand for each of the product categories. The analysis suggested that in theory product substitutions could offer non negligible contributions to the fulfilment of the Belgian Kyoto target.

However given the low absolute levels of these potentials as compared to the total emission reduction that Belgium has to achieve, the important question is whether these specific product-related emission reduction potentials can be extrapolated to other products categories and other consumption patterns.

The cost analyses indicated that if the theoretical potential from product substitution is significant, this substitution seems to be less cost-efficient than technology improvements within the production and waste treatment system itself.

The level of confidence of this conclusion is however low given the high uncertainty level of the cost data for the different technologies and products.

Considering the weak quality of these data, an optimisation based on total system cost and an approach based on fixed scenarios and associated cost calculations, eventually using cost ranges, could be combined as mutually complementing tools.

The examples studied also indicated that both the necessary instruments and the geographical level for implementing them in order to achieve these potentials have to take into account the specificity of each product category : this specificity relates to uncertainty but also to the openness of the Belgian economy which is more or less important from one material to the other and hence from one product to the other.

Indeed, the European level could be more appropriate for some product categories. In general product-related measures also require European co-ordination. The Integrated Product Policy currently under discussion could offer such a framework.

Finally, this project has also shown the importance of systematic recording consumption figures of key product groups in physical terms (and not only financial flows data) as a condition for properly assessing the environmental benefits of changes in consumption patterns.