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Greenhouse Gas emission from Transportation associated with French Consumption

An input-output analysis approach

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Master of Science in Engineering and ICT

Submission date: June 2008

Supervisor: Edgar Hertwich, EPT

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Department of Energy and Process Engineering

Problem Description

Energy use for transportation in France amounts to 52 millions tonnes of oil equivalent per year. Considering the low-emission associated with French electricity, efforts to reduce GHG emissions in France should be focus on the transportation sector. Here a simple input-output model of the French Economy will be constructed and used to quantify the transportation requirements for consumption in France.

The following questions should be considered in the thesis:

1. What are the GHG emissions associated with the transportation of goods for French consumption? What are the emissions associated with transport of goods outside France? What are the emissions associated with transport of goods inside France?What are the emissions associated with transport of goods from other EU countries?
2. What changes in French consumption patterns could be made which would result in the greatest reductions in associated GHG reductions?
3. How should the French transportation infrastructure evolve in a carbon constrained economy?
4. What recommendations could be made for French businesses and policy-makers about effective strategies under European carbon-constraints? What recommendations could be made for French businesses and policy makers about effective strategies under global carbon-constraints?

Assignment given: 30. January 2008
Supervisor: Edgar Hertwich, EPT

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Greenhouse Gas Emissions from Transportation Associated with French Consumption: An Input-Output analysis approach

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Abstract

This thesis applies the framework of input-output analysis to the transportation of goods driven by the consumption of French household. It was found that transportation of goods amounts to 7 % of the average 22,4 tons of CO_2 emitted by French households and that 78 % of the emissions occured inside the EU 15, France included. In fact, 92 % of the tons consumed by French households are produced inside the EU 15 and are mainly transported via road whereas the remaining tons, coming from other countries, are mainly transported by ships. Consequently, the carbon efficiency of the transportation inside the EU15 is low compared to imports from other countries since road transportation emits 40 times more carbon dioxide per tonne-kilometer transported.

This demonstrates the need for an ambitious policy of transfer from road to rail, water or maritime ways via the development of the appropriate infrastructure and the combination of the advantages of the different modes, flexibility of the road transporation associated with mass and environmentally friendly transportation of rail, waterway and maritime mode.

Furthermore, the study gives some knowledge on the indirect emissions associated with French households, which correspond to the combination of the emissions driven by the transportation of goods with the emissions associated with the production of these goods. It was found that petroleum products, food related sectors and the coal sector are the main contributor of the indirect emissions associated with French households representing as much as 57 % of them. As a result, future studies should focus on those sectors in order to isolate path of improvement both in production, consumption and transportation patterns.

Acknowledgements

I would like to thank all the persons who helped me during my master thesis, especially Dr. Troy Hawkins, my main advisor, for his guidance and his kindness in helping me set priorities all along the project.

I would also like to thank all the industrial ecology department for all the learnings I have been able to make during my stay in Norway and their helpfulness.

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Glossary

ADEME	Agence De l'Environnement et de la Maîtrise de l'Énergie (Energy Conservation and Enviroment Agency)
GHG	GreenHouse Gas
INSEE	Institut National de la Statistique et des Études Économiques (National Statistical Institute for Economic Studies)
MEDAD	Ministère de l'Écologie, du Développement et de l'Aménagement Durables (Ministry of Ecology, Sustainable Development and Planning)
DOM	Départements d'Outre Mer (Overseas French departements)
TOM	Territoire d'Outre Mer (Overseas French Territories)
UNFCCC	United Nations Framework Convention on Climate Change
NES	Nomenclature Économique de Synthèse (Synthetique Economic Nomenclature)
NST	Nomenclature Statistique des Transports (Transport Statistic Nomenclature)
ESA	European Statistical Account
CITEPA	Centre Interprofessionnel Technique d'Études sur la pollution atmosphérique (Inter-professional Technic Centre for Studies on Atmospheric Pollution)

Chapter 1

Introduction

Transportation is one of the three basic human activities, the other being housing and food.

Nowadays, transportation refers to an essential activity of our economic world which is divided in two clearly distinct field.

- Transportation of people usually divided in two categories : the short-distance commuters and the long-distance travelers.
- Transportation of goods between production facilities and from production facilities to the places where they are consumed. This includes the transportation of waste.

In this thesis, we take a close look on the impact driven by the transportation sector on Climate Change.

Climate change is driven by greenhouse gas emissions (GHG) which concerns emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O).

In France, the relationship between the economy and GHG emission is distinct in that the majority (80 %) of electricity is generated using nuclear reactors.

So, carbon intensive electricity sources such as coal, natural gas, and oil accounts for only 10 % of the French electricity mix.

Thus, France has already adopted a low-GHG electricity source, which means that meeting its Kyoto targets will require targeting other sources of GHG.

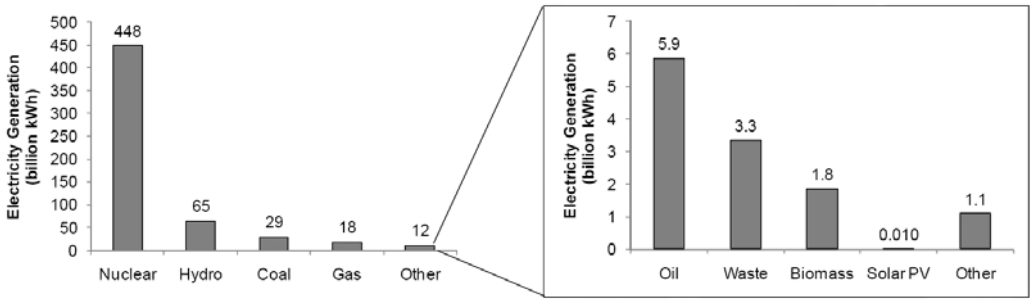

Figure 1.1: French electricity mix

Figure 1.2 shows that the energy use for transportation in France amounts to 52 million tonnes of oil equivalent per year (IEA, 2005). 50 of them comes directly from the use of petroleum products. The second most petroleum intensive activity, residential, uses 10 millions tonnes of oil equivalent per year, a fifth of the precedent value.

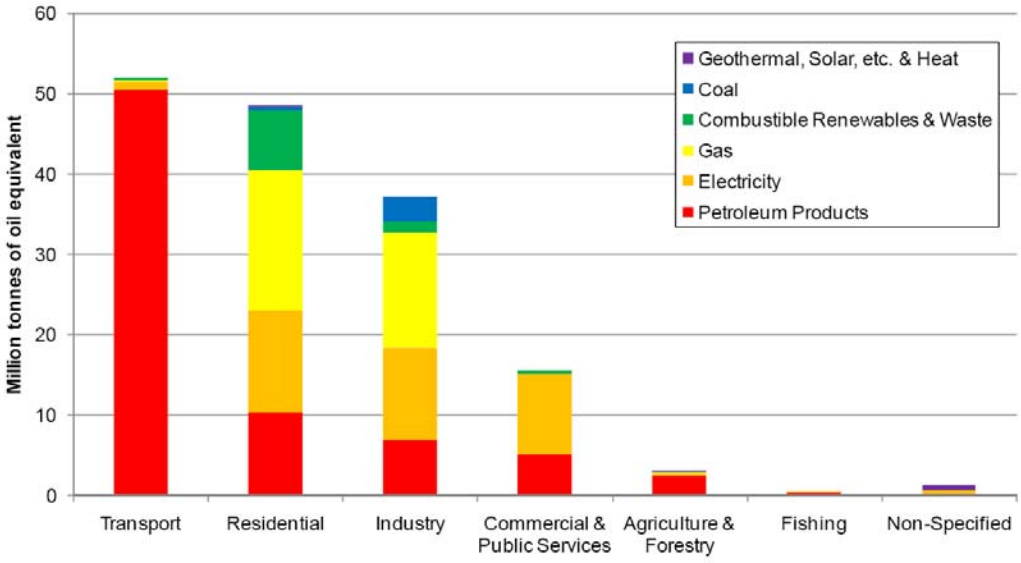

Figure 1.2: French energy consumption

Thus, it makes sense to focus efforts to reduce GHG emissions in France on the transportation sector.

Actually, according to the Inter-professional Technic Centre for Studies on Atmospheric Pollution (CITEPA) [7], the emissions of transportation counts for 21,7 % of the metropolitan France GHG emissions in 2004, and together with residential is one of only two sectors which has its emission growing and higher that the reference Kyoto level of 1990.

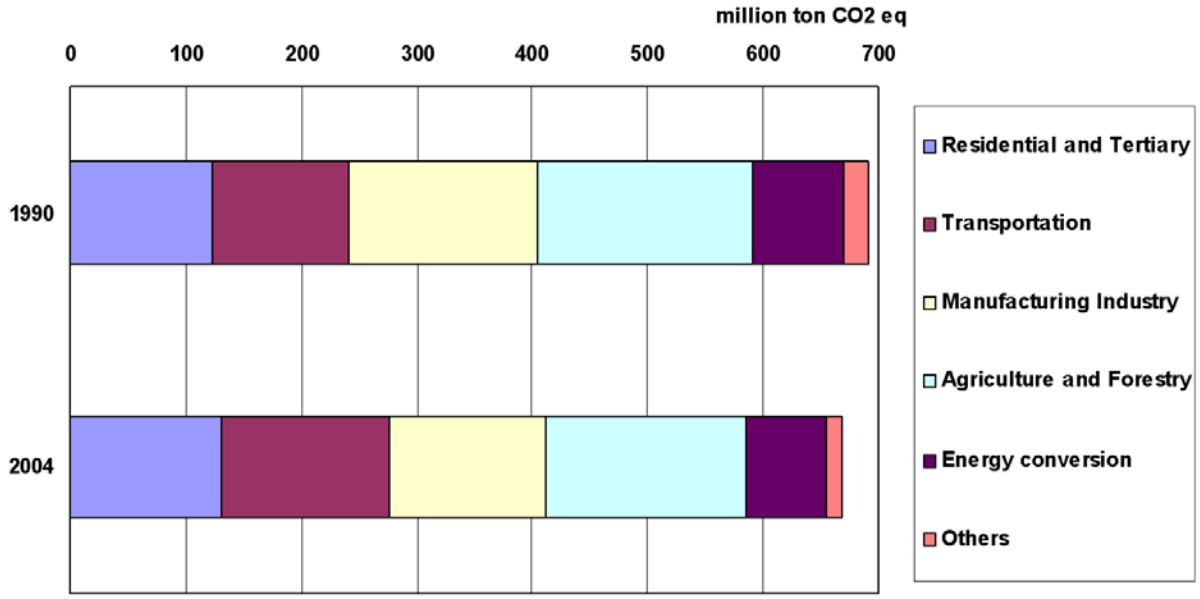

Figure 1.3: The emission of GHG in France [1]

To reduce the impact of transportation, most discussion in France has centered around alternative transportation options for commuters and travelers.

In contrast, this thesis is concerned with the emissions associated with the transportation of goods driven by French households' consumption. Nevertheless, the transportation of people is tackled to the extent that the two transportations share the same infracstructure and, as such, a strong connection exist between the two.

The method applied here is based on the use of input-output models which offer a valuable tool for the analysis of coupled economic-environmental systems because of their ability to track the economy activity and emissions associated with entire supply chains and circular flow within an economy.

This thesis focuses on the national and metropolitan level and on the consumption driven by households' final demand.

In 2005 , the metropolitan French population accounts for 59 419 thousands person and 25 732 thousands households giving a average household size of 2,31.[8]

The analysis scheme followed in the thesis stands as follows

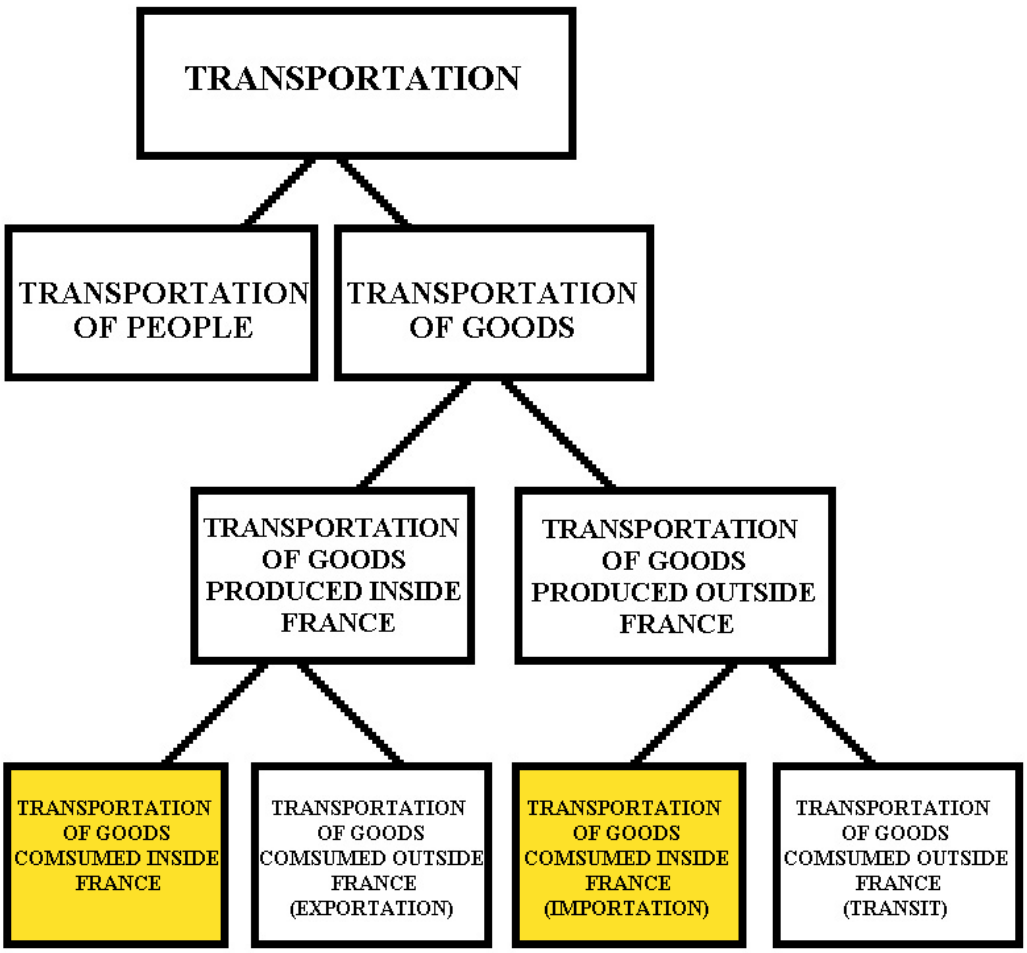

Figure 1.4: The analysis path

Transportations concerning households are colored on figure 1.4

The chapters of the thesis are the following.

- **Chapter 2** explains the methodology of the IO Analysis used in the thesis. The main idea is to track down the material flow of goods in term of tonne-kilometers data and than, based on the emission factor of each transport mode to estimate the GHG emissions.

- **Chapter 3** introduces results of the analysis and discusses them. As explained before, the thesis focuses on GHG emissions associated with the transportation of goods dedicated to French household consumption. As such, results concern possibilities of emission reduction associated with shifting from carbon intensive transportation mode to less carbon intensive ones and those associated with changes in consumption patterns.

- **Chapter 4** summarizes the contribution of this thesis and suggests future work.

Chapter 2

Methods

The method applied here is to use the input and output tables given by statistical offices on the French economy to create a model assessing the GHG impact of transportation.
The advantage to use IO tables is their ability to keep track of the circular flows within the economy, then giving the possibility to assess the responsibility of each sector in the GHG emissions.

Based on the litterature provided by the NTNU course entitled "Input-Output Analysis, Trade and Environment" [9] and other main studies on Input-Output such as "The OECD Input-Output database" [10], Edgar G. Hertwich and Glen P. Peters works [11] [12] and a recent study on "Food-Miles and the Relative Climate Impacts of Food Choices in the United States" [13], the analysis of transportation was built on a three step basis:

1. Determination of the different total output according to final demand. This corresponds to basic IO analysis developed by Leontief and described in Eurostat [14] and UN guidelines [15].

   Actually, the total output of an economy $\mathbf{x}$ can be expressed as the sum of intermediate consumption, $\mathbf{Ax}$, and final demand $\mathbf{y}$ as follows:

   $$\mathbf{x} = \mathbf{A} * \mathbf{x} + \mathbf{y} \tag{2.1}$$

   $$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-\mathbf{1}} * \mathbf{y} \tag{2.2}$$

   Applied to an arbitrary final demand, equation 2.2 allows the determination of the corresponding economical output.

2. Determination of the impact in term of Ton-kilometers driven according to final demand. This corresponds to adding a transportation dimension to the economical IO model described above.

$$\mathbf{f_{tkm}} = \mathbf{F_{tkm}} * \mathbf{L_{IxI}} * \mathbf{y} = \mathbf{F_{tkm}} * \mathbf{x} \tag{2.3}$$

3. Determination of the environmental load driven by final demand. This corresponds to adding an environmental component, here GHG emissions, to the coupled economical - transportation IO model described above

$$\mathbf{f_{CO_2}} = \mathbf{F_{CO_2}} * \mathbf{F_{tkm}} * \mathbf{L_{IxI}} * \mathbf{y} = \mathbf{F_{CO_2}} * \mathbf{F_{tkm}} * \mathbf{x} = \mathbf{F_{CO_2}} * \mathbf{f_{tkm}} \tag{2.4}$$

The structure of this chapter is following this scheme and presents the practical framework of the analysis.

2.1 Economical Data

In order to achieve the first step of the model, it is necessary to get the direct industry requirement matrix **A**.

The French Input-Output table used in the analysis is based on the French Nomenclature called Nomenclature Économique de Synthèse (NES). [16] The IO table is for the year 2004 and was created by disaggregating the data on the European Statistical Account website (ESA) using the fixed product sales structure (industry technology) assumption and shares from the data provided by the National Statistical Institute for Economic Studies (INSEE). This nomenclature was available on a 116 disaggregated level for years 1999 up to 2004. [17]

The intermediary consumption is presented as a flow matrix **Z** containing use of both foreign and domestic industries . To obtain, the direct industry requirement matrix **A**, flows are normalized by the total domestic industry output **g**.

$$\mathbf{g} = \mathbf{Z} * \mathbf{i} + \mathbf{y} - \mathbf{M} \tag{2.5}$$

$$\mathbf{A} = \mathbf{Z} * \mathbf{g}^{-\mathbf{1}} \tag{2.6}$$

M corresponds to the import which is given in the IO table at basic price.

Then 2.5 gives the domestic output, **g**. Nevertheless, for the normalization process, the vector **g** needs to have all its components different of zero.

The industry requirement flow matrix **Z** are shown in appendix H.

2.2 Impact Data

The Impact part of the model consists in the creation of the normalised *tkm* stressor matrix, $\mathbf{F_{tkm}}$ and the normalized CO_2 stressor matrix $\mathbf{F_{CO2}}$.

The Data concerning the ton-kilometers were taken from the SITRAM database [18], and data concerning greenhouse gas emission are taken from a software made by the Frenh Energy Conservation and Enviroment Agency (ADEME) and dedicated to firms transporting goods.[5]

The first difficulty met was to build a connection between the tkm data and the IO table. Actually, as the two set of data did not share the same nomenclature, a bridge beetween them was created.

2.2.1 Linking nomenclatures

The Sitram Database is based on the NST nomenclature which accounts four differents level of aggregation (10, 19, 52 or 175 categories of products). The database used in the thesis was obtained through the Ministry of Ecology, Sustainable Development and Planning (MEDAD) on March 12^{th} 2008 and are on the most disaggregated level, 175 products, for all transportation mode, except for the domestic rail mode which has 10 sectors.

In order to adapt these raw data to the economical input-output model, a bridge between the NES nomenclature and the NST nomenclature is needed. Unfortunately, no direct connections are found in the litterature. So, the bridge bridge was built according to the correspondance tables I was able to obtain.

As such, the construction of the bridge was a three step process :

1. Correspondance table between NES and CPA2002 (Nace rev 1.1): Available for all products on the most disaggregated level. [19]
   The main difficulty for this correspondance was the presence in the NES sectors of a distinction between non-market and market. It was solved by making allocation based on the name of the categories or making a hypothesis.

2. Correspondance table between CPA2002 and CPA2008 (Nace rev.2): Available for all products on the most disaggregated level. [20]

3. Correspondance table between CPA2008 and NST: Available for almost all products on the most disaggregated level. [21]
   there were seven cases where personal judgement had to be used to create the bridge entries for products which are absent from the correspondance table.

They concern:

- Mine wood (code NST 52)
- Steel hoop and strip, tinplate (Non-ECSC) (code NST 546)
- Phosphates Salt, Crude, Natural (code NST 713)
- Dephosphorisation scories (code NST 721)
- old package (code NST 991)
- old construction firms' material, old circus car and materials (code NST 992)
- Moving out furniture (code NST 993).

These cases are further explained in appendix A.2

‘ The correspondance table between the NES and the NST nomenclature is then calculated as follows:

$$\mathbf{b_{NES-NST}} = \mathbf{b_{NES-CPA_{2002}}} * \mathbf{b_{CPA_{2002}-CPA_{2008}}} * \mathbf{b_{CPA_{2008}-NST}} \tag{2.7}$$

The table obtained shows the repartition by sector. However, the correspondance table are generally normalized according to the output of each sector. So, the table based on sector distribution has been modified on a table based on the output of each sector.

To illustrate the difference between the two distributions, table 2.1 shows the difference between the two bridges for the live animal NST sector (NST code 001). Actually, the sector based bridge built through equation 2.7 shows that the live animal NST sector corresponds to three NES sectors: GA01, GA02 and GA03. To obtain the output based bridge shown in table 2.1, the following calculations are then done:

$$\mathbf{b_{NES-NST_{GA01}}} = \frac{\mathbf{x_{GA01}}}{\mathbf{x_{GA02}} + \mathbf{x_{GA03}} + \mathbf{x_{GA01}}} = \mathbf{0,97} \tag{2.8}$$

$$\mathbf{b_{NES-NST_{GA02}}} = \frac{\mathbf{x_{GA02}}}{\mathbf{x_{GA02}} + \mathbf{x_{GA03}} + \mathbf{x_{GA01}}} = \mathbf{0,01} \tag{2.9}$$

$$\mathbf{b_{NES-NST_{GA03}}} = \frac{\mathbf{x_{GA03}}}{\mathbf{x_{GA02}} + \mathbf{x_{GA03}} + \mathbf{x_{GA01}}} = \mathbf{0,02} \tag{2.10}$$

001	output based	Sector based
GA01	0,88	0,97
GA02	0,07	0,01
GA03	0,05	0,02

Table 2.1: Difference in NES-NST bridge coefficients according to the nature of repartition: Sector based or Output based (Live animal NST sector example)

In the case of live animal, the differences between the two bridges are small, the NES sector GA01 remaining the sector with the highest coefficent. However, the differences between bridges changes can be more significant for other products.

For the analysis part, the bridges based on output distribution has been used and is reported in appendix H.

2.2.2 Domestic Data

2.2.2.1 Ton kilometers Data

The tkm domestic data as the tkm import data are taken from the SITRAM database on March 12^{th} 2008. Although these data are not freely available, a free version with less data is available on the Ministry's website [18].
The domestic data are available in tonnes (t) and tonne-kilometers (tkm).

The description of the SITRAM Database is given in appendix A but one should note that over the 175 products of the NST nomenclatures, only 170 were available in the database provided.
The uncertainty related to these missing products is low as shown in appendix table E.1.

The data available in the dabase concerns each region of France and therefore was sum up to describe the national flow corresponding to the purpose of this thesis.

2.2.2.2 Emissions Data

Because of the structure of the analysis shown by equation E.1, the emission data has to be coherent with the tkm data, which means that they have to share the same distinction between transportation mode.

In the domestic SITRAM database, five transport mode are taken into account:

- Rail
- Road for own account
- Road for other account
- Waterway for own account
- Waterway for other account

where:

  - **transport for other account** means paid transportation of goods for a third party, for example, companies selling transportation services to other companies.
  - **transport for own account** means all transportation which is not accounted as transport for other account.

The differentiation between the two accounts is interesting in term of responsibilities and logistic. Actually, the results show that transport for own account concern short-distance transportation whereas long-distance transportation are realized by transport for other account. The main results and discussion coming from the distinction between these two kinds of account are further explained in subsection 3.2.1.

However, this differentiation between own and other account does not exist in the ADEME software EpE Module transport fret [5]. As a result, the distinction was created using data on 2004 vehicle park for the two types of account. (See appendix D for further description).

Finally, the emission factors stands as follows:

S_CO2_tkm_dom	kg CO2-e per t-km	lower limit	upper limit
Road (other account)	0,22	0,18	0,26
Road (own account)	0,22	0,18	0,26
water (other account)	0,038	0,030	0,045
water (own account)	0,038	0,030	0,045
Rail	0,0075	0,0068	0,0083

Table 2.2: The Domestic emission factors [5]

2.2.3 Import Data

2.2.3.1 Ton kilometers Data

The analysis concerning import data follows the same structure as the one concerning domestic data.

Based on the SITRAM database, the countries of the world are divided in four levels, p1 the most aggregated level to p4 the most disaggregated level. The database used in the analysis concerns the level p3 made of 42 categories (see Appendix C)

The import database gives only values in tons and millions euros. To get the data in ton-kilometers, distances have been estimated by taking a reference city for each of the 42 categories and calculating the distances seperating them to the reference city of each region. The distances are shown in appendix table E.7.

Furthermore, as in the domestic data, some products are missing. Actually, 8 products are missing, 3 more than in the domestic data. Nevertheless, the effect of these missing products on model results is low as shown in appendix table E.5. Actually, based on this table, the uncertainty is concentrated in the Other transportation mode sector, for which an emission factor of zero was used.

The data available in the dabase concerns each region of France and therefore was sum up to describe the national flow corresponding to the purpose of this thesis.

2.2.3.2 Emissions Data

In the import SITRAM database, five transport mode are taken into account:

- Maritime transportation (1 emission factor)
- Railway transportation (16 different emission factors: differentiation between European Union countries. Average EU value taken for non-EU countries)
- Air transportation (3 different emission factors: Differentiation based on distances between France and the foreign countries)
- Road transportation (1 emission factor)
- Waterway transportation (1 emission factor)
- Other transportation mode (pipelines and own propulsion goods) (1 emission factor equal to zero)

In order to create a consistent data set of emissions factors, some hypothesis were made, the most significant one being the zero emission factor given to other transportation mode.
The hypothesis are all explained in appendix D, the following table showing as an example the emission factors for Germany.

S_CO2_tkm_Germany	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,032	0,026	0,038
Air transportation	1,028	0,822	1,233
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

Table 2.3: The emission factors of Germany

Chapter 3

Results

This chapter presents the results obtained with the running of the model described in 2.

The thesis focuses on Household consumption. As a result, emissions associated with transportation were completed with those coming from production and direct emissions of households, these two being calculation based on NAMEA data.

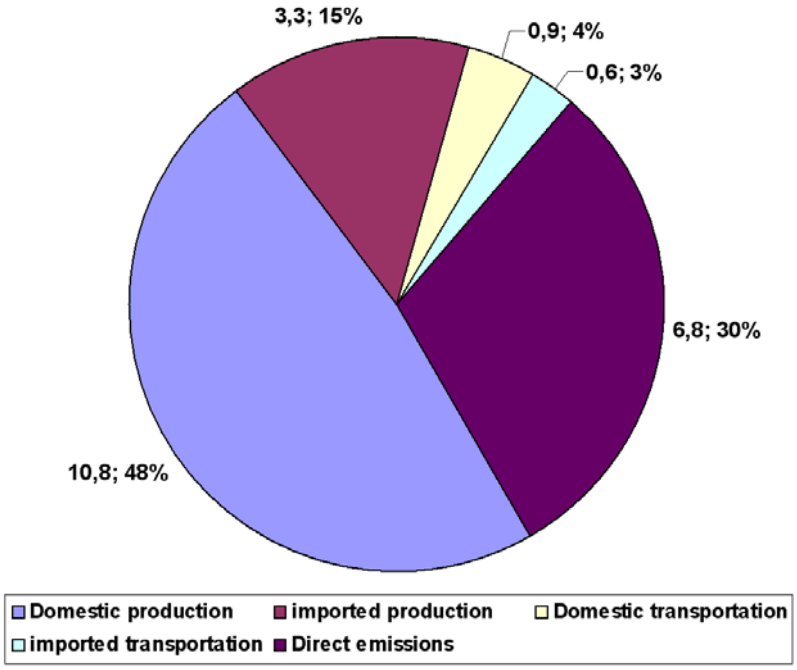

Figure 3.1: The total CO_2 emission driven by Household consumption (22,4 tons CO_2 per household)

The total emissions associated with the consumption of an average French household correspond to 22,4 tons CO_2.
Of these, 7 % are generated by the transportation of goods, 63 % by the production phase and 30 % by the use phase or direct emissions from households.
As shown on figure 3.1 , imports hold a high share of total emissions.
The transportation of imported goods represents 41 % of the emissions due to transportation of goods whereas the imported production counts for 24 % of the production phase.

Concerning methods, a special note to keep in mind is that the mirrored economy assumption was used.
Actually, the mirrored economy assumption consists in taking the French technology coefficients for foreign countries. In these conditions, differences between France and foreign countries are omitted. Of these, two are particularly important:

- France have a low carbon intensive electricity production since carbon intensive electricity sources such as coal, natural gas, and oil represents only 10 % of the French electricity mix.
  This not the case for many european countries such as Germany whose electricity mix is mainly based on coal power plants. As a result, emissions are underestimated.

- Nevertheless, the EU 15 technology coefficient to the exception of the electricity production can be reasonnably assumed to be the same as the French ones.
  The case is different when dealing with developing countries and emerging countries such as those of Africa, Asia or Other America.
  Actually, these countries have not yet achieved the European technology level, leading to a higher carbon intensive production of goods. As a consequence, emissions are particularly underestimated for these countries.

A way to better include imports would be to realize a multi-regional input-output (MRIO) analysis [22] in which each different economy of the world would be modelized by an appropriate input-output table.

Nevertheless, in spite of these underestimations which could be more exactly evaluated by using a comprehensive multi-regional input-output analysis, the results obtained with the model are full of meaning as the following sections show.

3.1 Decomposition by sectors

The model gives results for the 116 sectors of the NES Nomenclature. For the presentation of the results, they were aggregated in ten relevant categories. Actually, the aggregation is based on a standard INSEE aggregration made of 16 sectors [23]. The relatively low carbon intensive sectors of this aggregation were then put together under the label "Other sectors".
As a result, the category "Other sectors" corresponds to the combination of the following sectors:

- Construction
- Trade
- Transports (excluded for production to avoid double counting)
- Financial activities
- Real estate activities
- Services to businesses
- Personal and domestic services
- Education, health and social work
- Administration

Another particularity was added to the standard Insee aggregation. Two sectors were removed from the Energy sector to be shown as single categories. They stand as follows:

- Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction
- Manufacture of refined petroleum products

Figure 3.2 shows in the ten categories described above the households' indirect emission, which, according to figure 3.1, represents 70% of the total emission driven by household consumption.

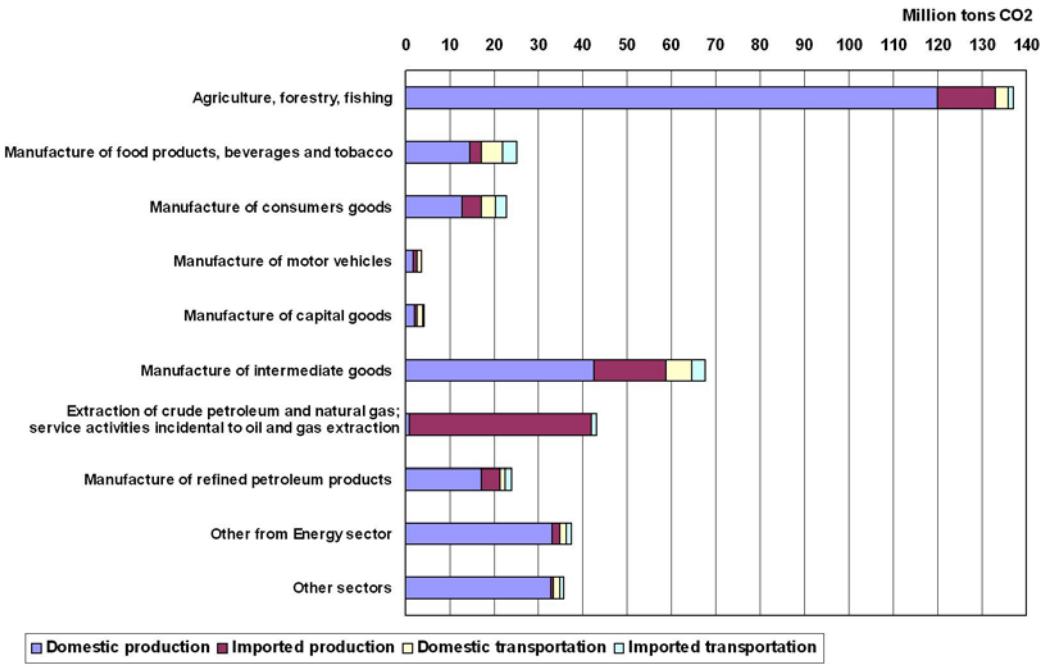

Figure 3.2: Decomposition in ten sectors of the French households' indirect CO_2 emission

Figure 3.2 shows that "Agriculture, forestry, fishing" is the most polluting sector, accounting for 31 % of the emissions driven associated with the combination of production and transportation of goods for French household consumption. The other predominant sectors in term of emissions are "Manufacture of intermediate goods", 17 %, "Extraction of crude petroleum", 11 %, "Other sectors", 9 % and "Other energy sectors, 9 %.

The manufacture of intermediate goods represents a high share of the of the emissions driven associated with the combination of production and transportation of goods. For this reason, this sector is split up in six categories whose names and emission shares are as follows:

- Mining and quarrying except energy producing materials, manufacturing of other non-metallic mineral products, 4,5 %.
- Manufacture of basic metals and fabricated metal products, 4,3 %.
- Manufacture of chemicals, rubber, plastic and chemical products, 3,6 %.
- Manufacture of wood, wood products, pulp, paper and paper products, 3,6 %.

- Manufacture of textiles, 0,4 %.
- Manufacture of electric and electronic components, 0,4 %.

An interesting outcome of figure 3.2 is the comparison between production and transportation responsibilities in the emission driven. Actually, the share concerning transportation of goods is quite low for the predominant sectors quoted above, between 3 % and 13 %.

A comparison can also be made according to the origin of the emissions. As such, it appears that the emissions of the predominant sectors are domestically emitted, except for "Extraction of crude petroleum" whose main share concerns imported production, 95 %. Actually, as France is not a country with geological reserves of oil or natural gas, its dependency from abroad on these particular products is high. This dependency for oil supply was the reason for the starting of the nuclear program after the 1973 oil crisis.

However, though figure 3.2 shows the responsibilities of each sector in the emissions driven associated with the combination of production and transportation of goods, it seems difficult to act on this basis to reduce carbon dioxide emissions. The model used here is more comprehensive and allows answers to the following questions:

- The model gives results in term of tons. This corresponds to a material flow and allows to answer to the question **"what goods are highly consumed by French households?"**.
  As such, tons results are directly connected to the consumption pattern of households and one way for them to reduce emission would be to lower the material flow of these goods.

- The model gives results in term of tkm. This allows answer to the question **"From where the goods consumed by French households come?"**.
  As such, tkm results can show the advantages in shifting from a distant supplier to a local supplier.

- The model gives results in term of CO_2 emissions. Though these results show as in figure 3.2 the sectors where the efforts in term of emission reduction should be done, they also provide answer to the question **"How carbon intensive the transportation of the goods consumed by French household is?"**.
  As such, CO_2 results when differentiated by transportation mode can provide an idea of the emission reduction resulting of a shift in transportation mode. This point is particularly adressed in section 3.2.

Figure 3.3 shows the three kinds of results generated by the model for the same ten categories of figure 3.2.

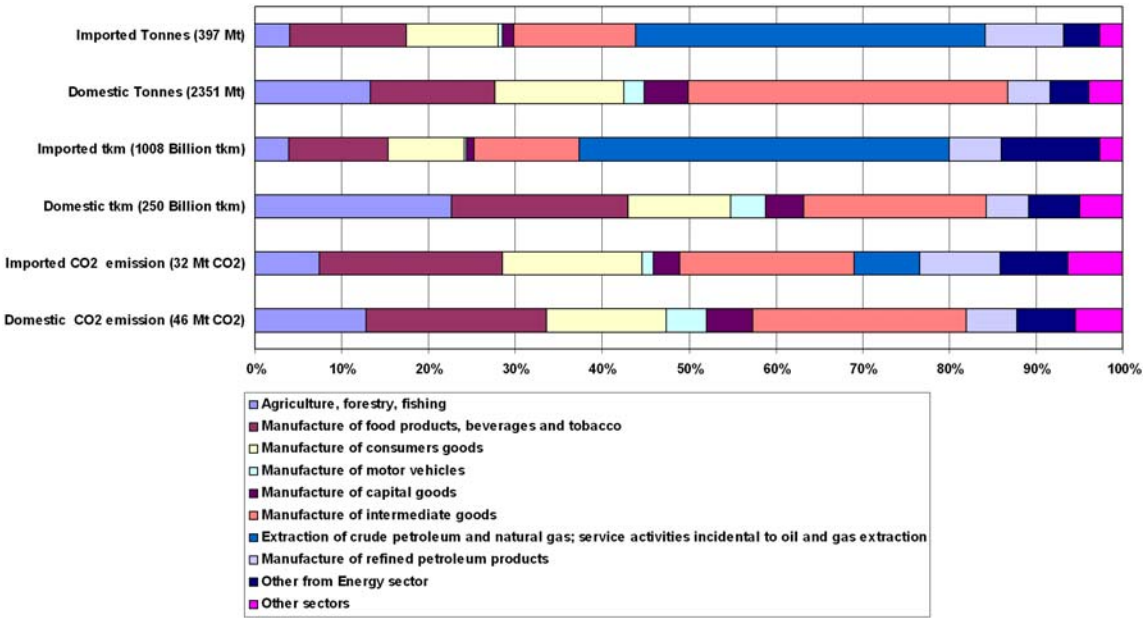

Figure 3.3: Decomposition in ten sectors of the tonnes, tkm and CO_2 emissions associated with transportation dedicated to Household consumption. In brackets are written the totals, sum for all the sectors

In term of material flow intensity, "Manufacture of intermediate goods" is the most intensive sector since 34 % of the tons transported to meet household consumption concerns this sector. Of these 34 %, only 6 % are imported meaning that the material flow concerning intermediated goods is mainly domestic.

The other predominant sectors in term of material flow intensity are "Manufacture of consumer goods", 14 %, "Manufacture of food products, beverages and tobacco", 14 %, and "Agriculture, forestry, fishing", 12 %.

The share of imports is relatively low for these other predominant sectors, between 5 and 14 %. Actually, the main imported goods are "Extraction of crude petroleum", 98 % of import share, and "Manufacture of refined petroleum products", 24 % of import share but they only represent put together 11 % of the tons transported to meet household consumption.

In term of tkm driven, "Extraction of crude petroleum" is the most intensive sector since 34 % of the tkm driven to meet household consumption concerns this sector. Of these, only 0,1 % are domestically driven meaning that the tkm driven concerning crude petroleum are mainly imported.

The other predominant sectors in term of tkm driven are "Manufacture of intermediate goods", 14 %, "Manufacture of food products, beverages and tobacco", 13 %, and "Other from energy sector", 10 %.

The share of imports is relatively high for these other predominant sectors, between 69 and 83 %. Actually, the main domestically driven goods are "Manufacture of motor vehicles", 75 % of domestic share, and "Agriculture, forestry, fishing", 59 % of domestic share but they only represent put together 9 % of the tkm driven transported to meet household consumption.

In term of CO_2 emission, "Manufacture of intermediate goods" is the most intensive sector since 23 % of the emissions associated with transportation of goods for household consumption concerns this sector. Of these, 36 % are emissions associated with imports meaning that the emissions concerning intermediate goods are shared one third/two third between imports and domestic transportation.

The other predominant sectors in term of emissions are "Manufacture of food products, beverages and tobacco", 21 %, "Manufacture of consumer goods", 15 %, and "Agriculture, forestry, fishing", 11 %.

The imports and domestic shares are almost the same for "Manufacture of food products, beverages and tobacco" and "Manufacture of consumer goods" since the import shares are respectively 41 % and 45 %. "Agriculture, forestry, fishing". Actually, the main imported goods in term of emission are "Extraction of crude petroleum", 99 % of import share, and "Manufacture of refined petroleum products", 53 % of import share but they only represent put together 10 % of the emissions associated with transportationof goods for household consumption .

As a first point, one should note that the predominant sectors in term of CO_2 emissions are different of those presented in figure 3.2. Actually, "Manufacture of food products, beverages and tobacco" and "Manufacture of consumer goods" each contributed 6 % of the emissions driven associated with the combination of production and transportation of goods ; but when considering transportation alone, their shares raises up to respectively 21 % and 15 % of the emission. This means that when focusing on emission reduction from transportation sector, these two sectors reveal their importance.

As a result, "Manufacture of consumer goods" is split up in four categories whose names and emission shares for transportation of goods only stands as follows:

- Manufacture of domestic equipment, 6,4 %.
  - Manufacture of furniture, 3,3 %.
  - Manufacture of sports goods, games, toys and others n.e.c., 2,0 %.
  - Manufacture of jewellery and musical instruments, 0,6 %.
  - Manufacture of domestic appliances, 0,4 %.
  - Manufacture of optical instruments, photographic equipment, watches and clocks, 0,1 %.
  - Manufacture of television and radio receivers, sound or video recording or reproducing apparatus and associated goods, 0,003 %.
- Manufacture of pharmaceuticals products, perfumes, soap and cleaning preparation, 5,6 %.
  - Manufacture of pharmaceuticals, medicinal chemicals and botanical products, 3,8 %.
  - Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations, 1,8 %.
- Publishing, printing and reproduction of recorded media, 1,8 %.
- Manufacture of clothing articles and leather products, 1,0 %.

The comparison of the tons results with the tkm results give also interesting outcomes. As explained before, the structure of tkm results is highly different of the tons results one meaning that some goods comes from far away countries. These goods corresponds to "Extraction of crude petroleum" and "Other from Energy sector" meaning that the French energy sources used in France are situated in far away foreign countries. Unfortunately, these goods are endemic, only able to be produced in particular region of the world. This means that it would not be possible to lay in supply of those goods from local source. One solution would be then to become less dependant on these energy sources by increasing the share of renewables which are locally energy sources. Actually, the development of renewable energy sources, associated with ambitious energy conservation campaign, lies within the scope of a 20 % GHG emission reduction as defined by the European council of march 2007. [24]

To reach this objective, wind power can avoid the emission of 300 g CO_2 per kwh produced [24] and solar panel/photovoltaic cells the emission of 600 g CO_2 per kwh produced [25].
The figures above come from the comparison with a fossil energy source such as oil, gas and coal.

Nevertheless, though France owns high possibilities to increase its share of renewables (see [26] for wind potential and [27] for solar potential), the use of petroleum products remains concentrated in the transportation sector as shown on figure 3.4 for which renewable energies cannot be used at the moment. A solution would be then to develop alternative to petroleum such as second generation biofuels and electric cars.However when shifting energy resources, one should be cautious and take into account the whole life cycle of the alternative proposed. For example, biofuel can compete with food in term of land use.[28]

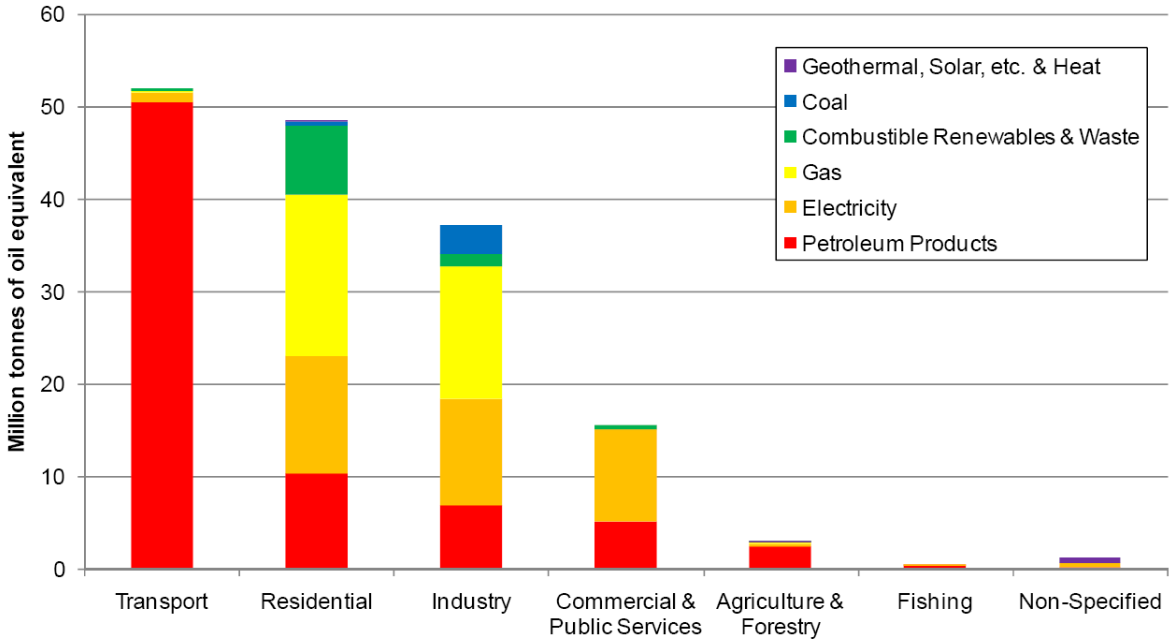

Figure 3.4: French energy consumption: Petroleum consumption concentrates in the transportation sector.

However, when comparing tkm results and the emission results, the structure changes once again and the first four predominant sectors of emission results match with the ones of ton results.

The share of "Extraction of crude petroleum" and "Other from Energy sector" is only of 10 % of the emission associated with transportation of goods for household consumption whereas they corresponded to 44 % of the tkm driven. This means that energy products are transported via a low carbon intensive transportation mode compared to other products. The issue of transportation mode is further explored in section 3.2 but one can already notice that as the structure of tons results and the emission ones is similar, a material consumption reduction of intermediate goods, food products, consumer goods and agriculture will provide the greatest emission reduction in term of a shift in consumption pattern or material efficiency.

	Reduction in thousand tons CO2 induced by a 10 % reduction in tons used	% reduction for emission associated with transportation of goods for household consumption	% reduction for emission associated with total household consumption (*)
Manufacture of intermediate goods	880	2,3%	0,15%
Manufacture of consumers goods	570	1,5%	0,10%
Manufacture of food products, beverages and tobacco	810	2,1%	0,14%
Agriculture, forestry, fishing	410	1,1%	0,07%
Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction	120	0,31%	0,02%
Manufacture of refined petroleum products	280	0,72%	0,05%
Manufacture of capital goods	170	0,44%	0,03%
Other from Energy sector	275	0,71%	0,05%
Other sectors	230	0,59%	0,04%
Manufacture of motor vehicles	130	0,33%	0,02%

(*) A reduction of 10 % in tons used will also imply reductions for emission from producers and use phase. These reductions are not taken into account here.

Table 3.1: Reduction of CO_2 emission associated with transportation of goods for household consumption induced by a 10 % reduction of tons used

3.2 Decomposition by transportation mode

Transportation mode have different carbon efficiencies (see appendix D). In order to show their relative difference in term of CO2 emitted per tkm driven, values are scaled to the cleanest transportation mode, maritime transportation.

	kg CO2-e per t-km	Relative to maritime
maritime	0,0056	1
rail domestic	0,0075	1,3
rail average EU 17(*)	0,023	4,1
waterway	0,038	6,8
road	0,22	40
Long-distance aircraft (> 4000 km)	0,481	87
Middle-distance aircraft (1000 à 4000 km)	0,997	179
Short-distance aircraft (< 1000 km)	1,028	185

(*) see appendix on emissions for details on rail factor of imported goods

Table 3.2: Emission factors

As such, low carbon intensive transportation mode are maritime, rail and waterways in comparison to high carbon intensive mode such as air and road transportation.

So, modal transfer seems a way to reduce GHG emission from the transportaion sector and following recommendations can be made:

- **for long distance**: avoid air transportation and favour maritime transportation. However, as described in subsection 3.2.2, most of the tons coming from far away countries are already transported via maritime ways.
- **for short distance**: favour rail and waterway in term of terrestrial mode. The emission reductions associated with this transfer is further detailed in subsection 3.2.3.

Furthermore, modal transfer should ensure fiability, flexibility and avoid transshipment. These conditions are necessary to the economic success of modal transfer.

3.2.1 Transportation of domestically produced goods

Only terrestrial transporation mode are taken into account for domestic transportation. Figure 3.5 shows the different results generated by the model for these terrestrial mode.

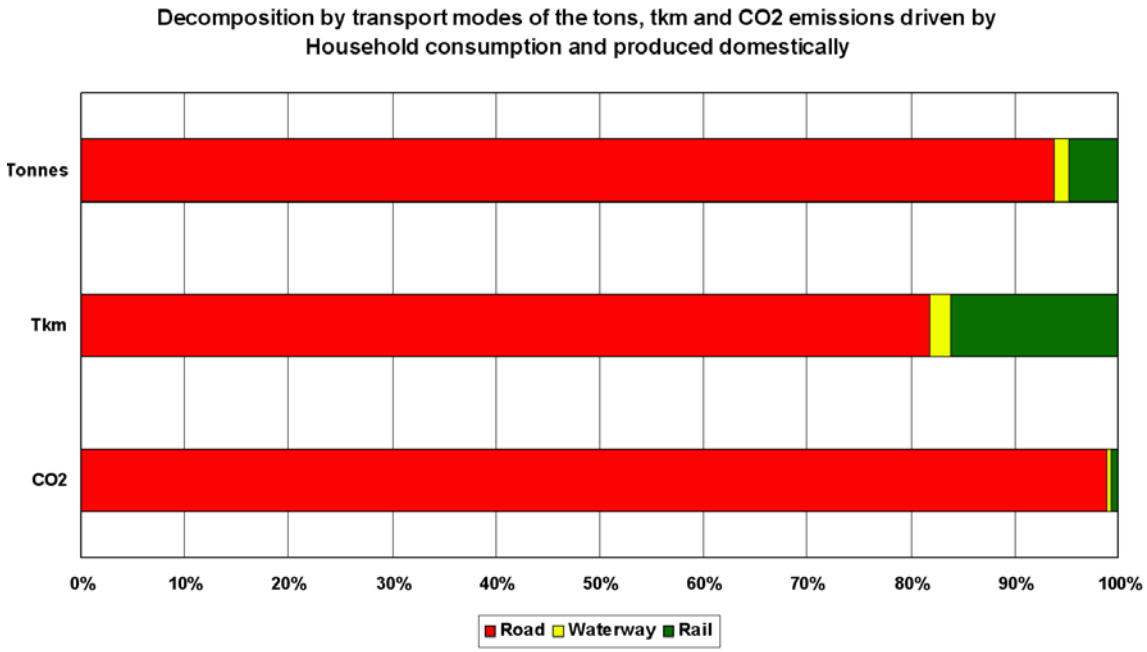

Figure 3.5: Decomposition by transport modes of the tons, tkm and CO_2 emissions driven by Household consumption and produced domestically

The first outcome is the tremendous share of road in the transportation of domestically produced goods for household consumption: 99 % of the emissions, 82 % of the tkm driven and 94 % of the tons consumed.
This is particularly interesting in the light of table 3.2 since road transportation emits respectively 6 and 29 times more CO_2 than waterway and rail transportations per tkm driven.
As such, it appears that France should search to readjust through modal shifting the way the tons consumed by households are transported.

However, one can already notice that rail is mainly used for long distance transportation.
Table 3.3 shows the average km driven by domestic transportation mode with differentiation between own and other accounts.

	km
Road own account	40
Road other account	128
Waterway own account	94
Waterway other account	168
Rail	359

Table 3.3: Average km driven by domestic transportation mode with differentiation between own and other accounts

Table 3.3 confirms the fact that the French rail network is mainly used for long distance transportation. The table also describes the difference between other and own account.
Other account which corresponds to paid transportation of goods for a third party deals with long distance transportation compared to own account. As such, the modal transfer will be easier to make for other account than own account, short distances travel not fitting very well with rail or waterway transportation.
This point is further analysed in subsection 3.2.3.

3.2.2 Transportation of imported goods

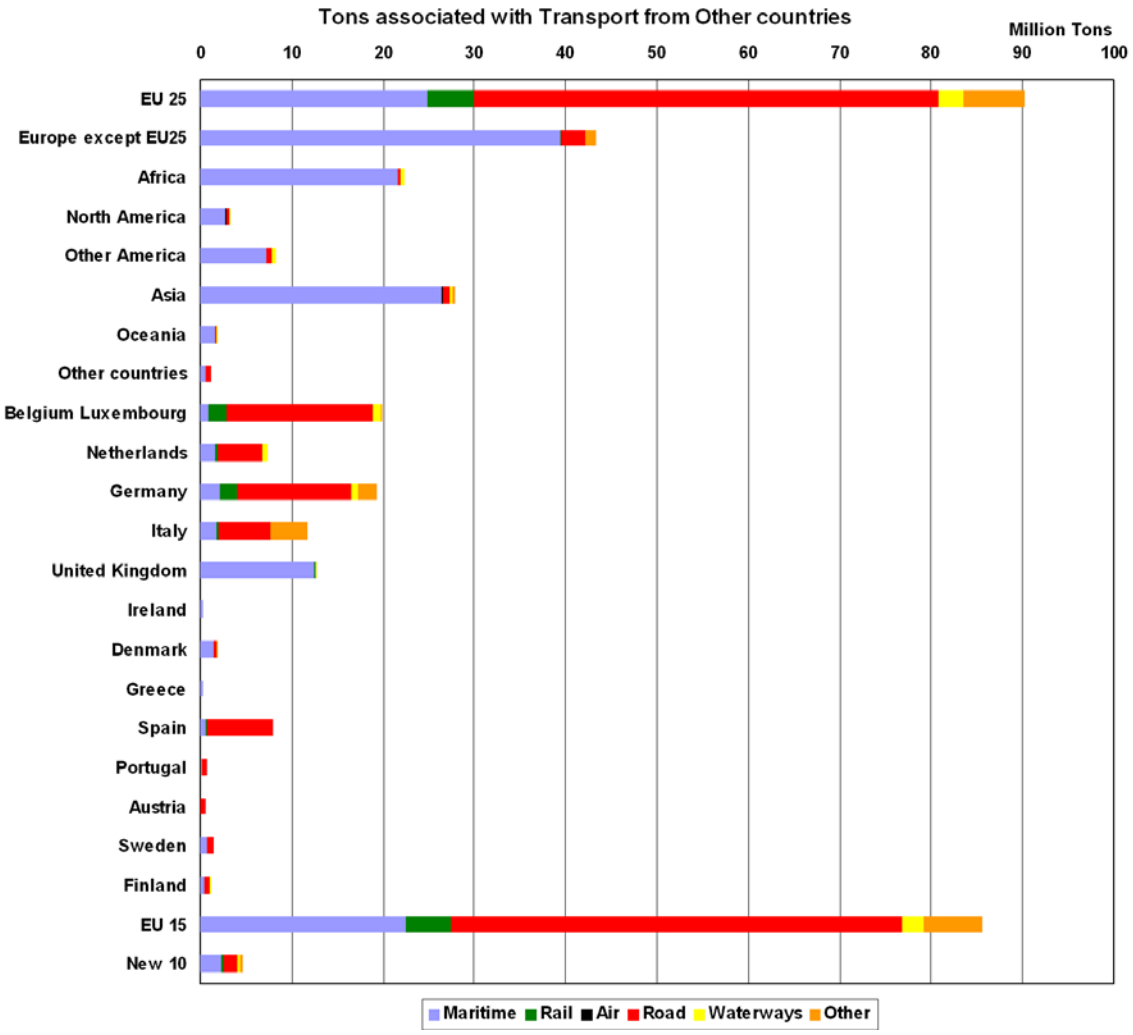

Figure 3.6: Tons associated with Transport from Other countries

The main trade partners of France are in Europe since 67 % of the tons imported for Household consumption come from Europe.
The other important trade partners of France are Asia (14 %) and Africa (11 %). Concerning Europe, the EU 15 covers by itself 43 % of the total tons imported for Household consumption. Furthermore, inside the EU 15, the main partners are the countries at the border since Germany, Italy, UK Belgium, Luxembourg, Netherlands and Spain accounts together for 40 % of the total tons imported for household consumption.

As shown on figure 3.6, the choice of transportation modes differs between imports from Europe and from other countries. Whereas tons outside Europe are mostly transported by bulk carrier and cargo multi-purpose, the tons in Europe are mostly transported by road.

As a result, transportation of goods in Europe appears mainly terrestrial, meaning that the alternatives to road can only be railways and in a lesser measure waterways.

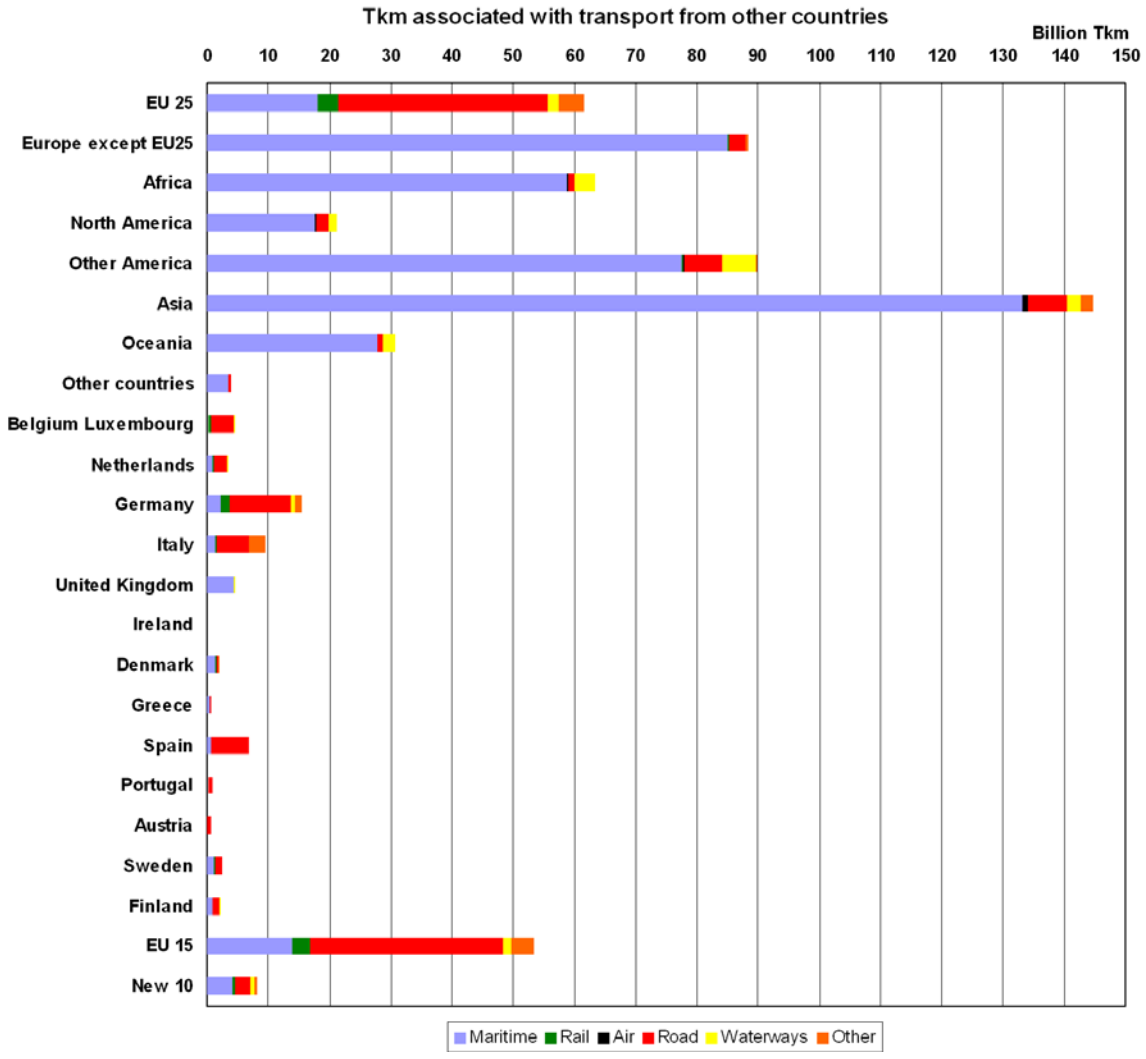

Figure 3.7: Tkm associated with Transport from Other countries

In term of tkm the share of Europe is lower, Asia and Other America being the main countries from which France imports.

Actually, Asia and Other America are countries situated respectively 7 000 km and 10 0000 km from France whereas main trade partners in Europe are border countries.

Nevertheless, the structure of the tkm is similar to the tons to the extent that Maritime transportation is the main mode used for importation except for EU for which road holds the highest share. This structure is different when dealing with CO2 emission as shown on figure 3.8.

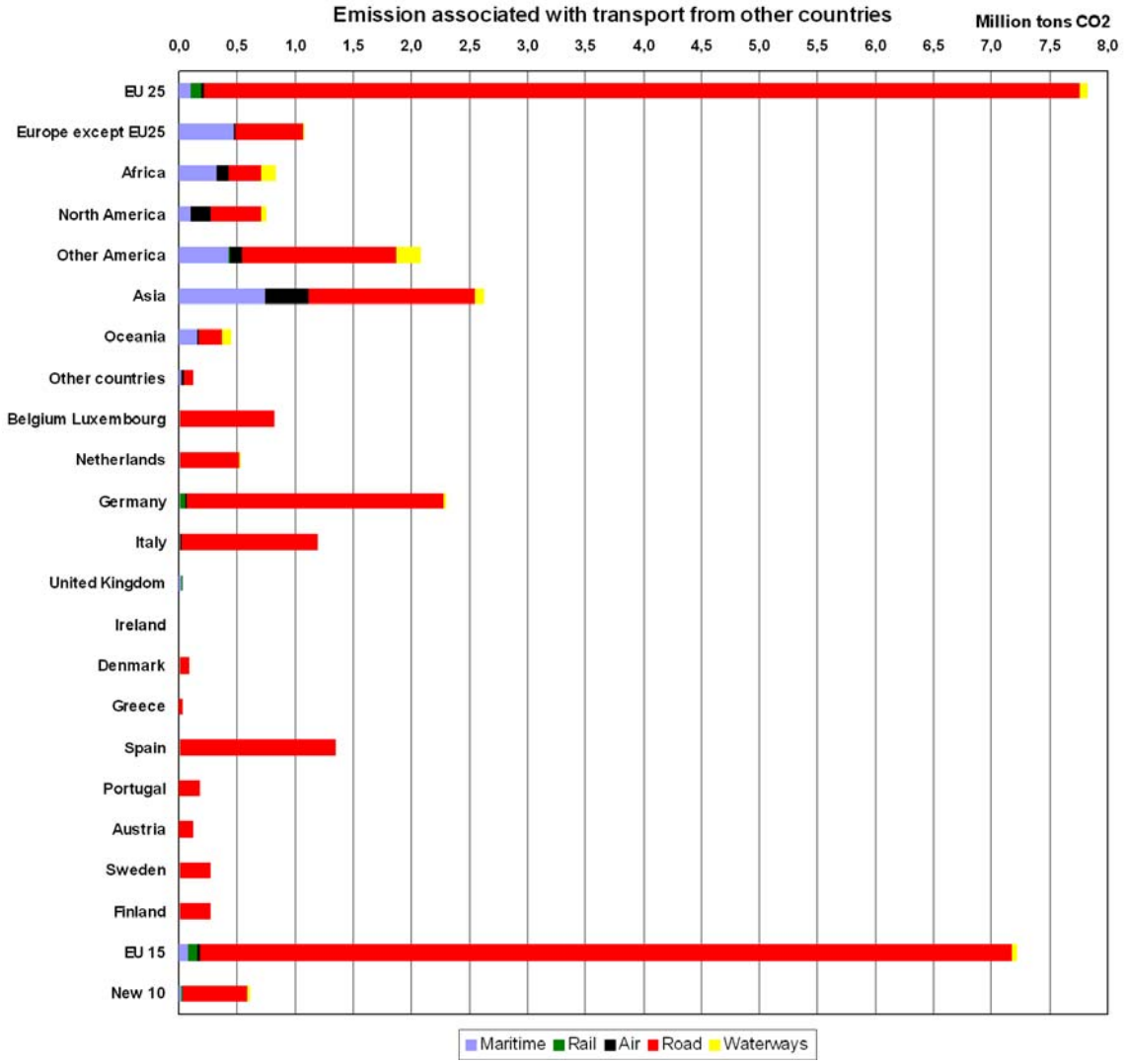

Figure 3.8: Emission associated with Transport from Other countries

Europe accounts for 56 % of the CO2 emission associated with transportation of goods from other countries.
Alone, EU 15 already represents 46 % of the CO2 emission whereas The border countries of France (Germany, Belgium, Luxembourg, Italy, Spain and Netherlands) represent 39 % of the CO2 emissions.

One transportation mode is mainly responsible for the emission: road.
Representing 75 % of the emissions, the responsibility of this mode reaches more than 97 % for the border countries.

As a result, I decided to adress in subsection 3.2.3 the possibility of shifting from road to less CO2 intensive terrestrial mode such as waterways and rail. Actually though the european rail network is the third longest network, only 8 % of goods are transported by rail against 21 % in 1970. [29]

3.2.3 Emission reduction associated with modal transfer

Three scenarios were considered:

Scenario 1 Looking at the share of each transport mode in term of tkm, 10 % were shifted from domestic road to domestic rail. In concordance with table 3.3, this transfer is likely to happen for other account since the other account is in charge of long distance road transportation for which the transfer is easier to made. Other account is also responsible for most of the domestic CO_2 emission 82 % compared to 17 % for own account. Emission reductions should then be focused on other account. The new shares are shown in table 3.4.

Scenario 2 Looking at the share of each transport mode in term of tkm, 10 % were shifted from domestic road to domestic rail and 10 % from domestic road to domestic waterways. In concordance with table 3.3, this transfer is likely to happen for other account as described in scenario 1.
The new shares are shown in table 3.4.

	road share	new road share	rail share	new rail share	waterway share	new waterway share
Domestic tkm share	82%	62%	16%	26%	2%	12%

Table 3.4: Change in the tkm shares of road, rail and waterway according to scenario 2

Scenario 3 Looking at the share of each transport mode in term of tkm, 10 % were shifted from road to rail for each of the border countries (Germany, Netherlands, Belgium, Luxembourg, Italy and Spain).
The new shares are shown in table 3.5.

	road share	new road share	rail share	new rail share
Germany	65%	55%	10%	20%
Belgium_Luxembourg	79%	69%	10%	20%
Spain	90%	80%	1%	11%
Italy	57%	47%	3%	13%
Netherlands	65%	55%	4%	14%

Table 3.5: Change in the tkm shares of road and rail according to scenario 3

The following tables present the reduction in emission provided by the scenarios.

	Million tons CO2 avoided	Million tons CO2 emitted before transfer mode	Percentage reduction
DOM	2,7	22,9	11,6%
TOT IMPORT + DOM	2,7	38,7	6,9%
TOTAL HH consumption	2,7	577,7	0,46%

Table 3.6: Reduction of CO_2 emission associated with scenario 1

	Million tons CO2 avoided	Million tons CO2 emitted before transfer mode	Percentage reduction
DOM	4,9	22,9	21,6%
TOT IMPORT + DOM	4,9	38,7	12,8%
TOTAL HH consumption	4,9	577,7	0,86%

Table 3.7: Reduction of CO_2 emission associated with scenario 2

	Million tons CO2 avoided	Million tons CO2 emitted before transfer mode	Percentage reduction
Germany	0,29	2,3	12,7%
Belgium_Luxembourg	0,09	0,8	11,4%
Spain	0,13	1,4	9,3%
Italy	0,18	1,2	15,1%
Netherlands	0,07	0,5	12,8%
EU 15	0,76	7,2	10,5%
TOT IMPORT	0,76	15,8	4,8%
TOT IMPORT + DOM	0,76	38,7	2,0%
TOTAL HH consumption	0,76	577,7	0,13%

Table 3.8: Reduction of CO_2 emission associated with scenario 3

The emission reductions obtained are particularly interesting since combined, the reduction in term of CO2 emissions reaches 15 % of the emissions associated with transportation of goods and 1 % of the total emissions driven by household consumption.

As such, modal transfer inside France and border countries seems like a good way to reduce emission. However, the feasibility of such a transfer will depend on the infrastructure available.

Will there be a need to construct new infrastructure with the cost associated with them?

Figure 3.9 presents the waterway network of France.

The French waterway network counts seven networks able to carry boat from 1 000 to 3 000 tonnes and convoys from 1 250 to 18 000 tons. Nevertheless, one can note that the network is concentrated on the eastern part of France though two western main cities, Nantes and Bordeaux, are covered by the network.
Another point is the great possibilities already available in term of connections maritime-waterway and rail-waterway.

Furthermore, the main cities of France can be supplied by waterways and there are possibilities of connection with waterways of Benelux and Germany. Actually, the rough estimation of table 3.9 based on the population of the main agglomerations situated along waterways shows that the waterway network is able to reach one third of the population. Besides, a new canal is being constructed whose layout can be seen on figure 3.9: the Canal Seine Nord Europe. Once completed, this canal will allow the connection between the "Paris-Rouen-Le Havre" network and the "Lille-Douai-Valenciennes-Dunkerque" network, creating a single network able to reach 22 % of the population. There is here a possibility to supply city centres such as the Paris one while avoiding nuisances and traffic jam caused by truck transportation.

Waterway network	population (1999)	% of total population
Lille - Douai - Valenciennes -Dunkerque	2 068 195	3,6%
Paris - Rouen - Le Havre	10 282 916	18,0%
Lyon - Avignon - Marseille - Montpellier	3 240 165	5,7%
Nancy - Metz	653 889	1,1%
Strasbourg - Mulhouse	661 690	1,2%
Bordeaux	753 931	1,3%
Nantes	544 932	1,0%

Table 3.9: Estimation of the population living nearby the waterways [6]

Figure 3.10 shows the main european rail corridor for transportation of goods.

Figure 3.9: The French waterway network [2]

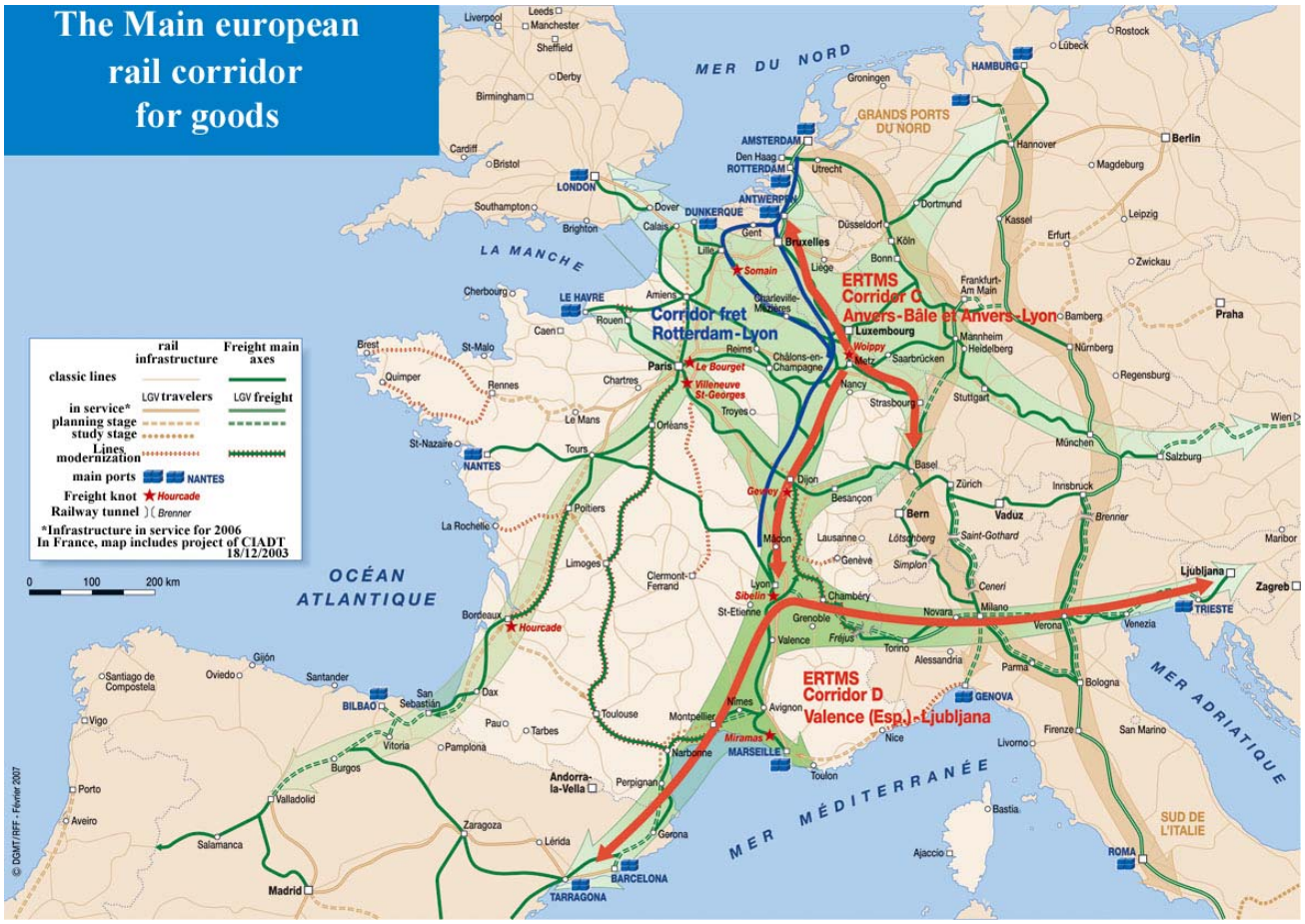

Figure 3.10: The main european rail corridor for transportation of goods [3]

The European rail network is already well structured though Spain is isolated at the moment, explaining why the tkm share of road transportation is so high for this country. Nevertheless, there are connection projects between San Sebastián and Valladolid on one part, Perpignan and Barcelona on the other part.
One should note that only High Speed Lines (LGV) are represented on figure 3.10, which are more rapid than trucks using highways (also represented).

Overall, it seems that only two part of France are badly covered by either waterway or rail network: Brittany and region around Clermont-Ferrand. Nevertheless, most of the infrastuctures needed for modal transfer already exist.

As such, the recommendations concerning the infrastructure are the following:

- Maintaining the existing rail and waterway infrastructure in a good state and proceed to modernization where needed.
- Develop connections between the different modes (maritime-water, rail-water, rail-maritime, rail-road, water-road). Combination of modes is likely to provide the greatest eco-efficiency by combining advantages of each mode.
- Provide a good services to transporters, in order to avoid any delays in supply chain.
- Provide a economic reasonable service. The mode transfer should include in its analysis competitiveness.

Furthermore, the cost associated with building rail infrastructure are less than constructing new roads, 1 million euros per km [30] compared to 5,6 millions euros per km [31]. As such, an increase of 10 % of the French rail network (3 000 km) will correspond to a cost of 3 billion euros.
However, rail transportation does not have the flexibility of road transporation; and so, a combined transportation appears a good solution. Combined transportation means the combination of at least two transportation modes for the same supply chain in which there is no transshipment and most of the transportation is realized by rail, waterways or short-distance maritime ways. In fact, only the good is transferred from a mode to another one as shown in figure 3.11.

According to ADEME, combined transportation is well adapted to distances superior to 600 km and transportation axes where there are massive flows of goods. [4]

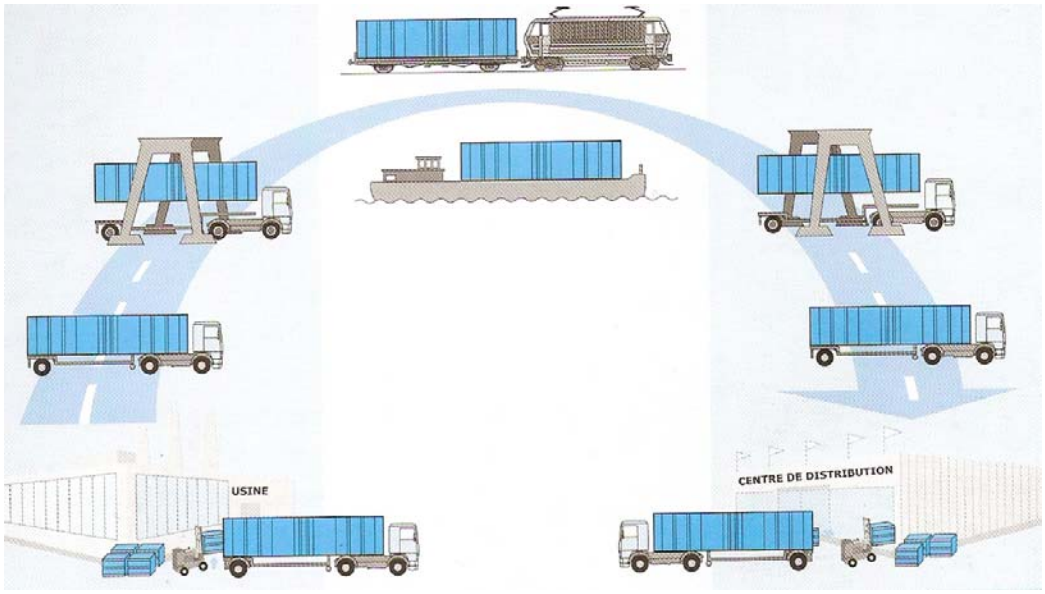

Figure 3.11: The principle of combined transportation [4]

3.3 The ten most emission intensive imported goods

	Million tons CO2 emitted	TOTAL IMPORT	TOTAL IMPORT + DOM	TOTAL HH consumption
Manufacture of refined petroleum products	1,47	9,3%	3,8%	0,25%
Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction	1,19	7,6%	3,1%	0,21%
Agriculture, hunting, trapping and related service activities	1,10	7,0%	2,8%	0,19%
Manufacture of other food products	1,10	7,0%	2,8%	0,19%
Mining of coal and lignite; extraction of peat	0,95	6,0%	2,5%	0,16%
Production, processing and preserving of meat and meat products	0,82	5,2%	2,1%	0,14%
Manufacture of pharmaceuticals, medicinal chemicals and botanical products	0,64	4,1%	1,7%	0,11%
Manufacture of beverages	0,57	3,6%	1,5%	0,10%
Manufacture of furniture	0,55	3,5%	1,4%	0,10%
Manufacture of dairy products	0,54	3,4%	1,4%	0,09%
Total 10 products	8,93	56,6%	23,1%	1,5%

Table 3.10: The ten most emission intensive imported goods and their share of total emissions associated with household consumption

As shown on table 3.10, these ten goods represent as much as 23 % of the total emission driven by the transportation of goods and 1,5 % of total GHG emissions associated with French household consumption. This is particularly interesting since the figures presented in table 3.10 are only related to imports.

The following subsections present a analysis concerning each of these goods regrouped according to their supply chain, for example petroleum products and food products.
Otherwise, the analysis follows the same structure:

- Presentation of the ten sectors which are the main consumer of the said good. This is done by analyzing the monetary flow matrix **Z**.
- Presentation of the ten sectors for which the good represents a high share of the direct purchase. This is done by analyzing the technology coefficient matrix **A**.

3.3.1 The petroleum products

Table 3.11 shows that two third of the crude petroleum is transformed into refined petroleum to feed transportation sectors (road freight and air transportation). Once again, this demonstrates how much the transportation by road is carbon intensive.

Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction		
Ten "Extraction of crude petroleum and natural gas; etc" most consumer sectors	Monetary flow (million euros)	% of the total flow of this product
Manufacture of refined petroleum products	17 856	67,2%
Gas, steam and hot water supply	5 910	22,2%
Manufacture of basic inorganic chemicals	1 496	5,6%
Sale, maintenance and repair of motor vehicles and motorcycles, retail sale of automotive fuel	560	2,1%
Construction and installation of buildings	210	0,8%
Wholesale trade and commission trade	171	0,6%
Civil engineering works	103	0,4%
Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction	55	0,2%
First processing of iron and steel	15	0,1%
Manufacture of pulp, paper and paperboard	15	0,1%

Table 3.11: Ten most consumer sectors of refined petroleum products

Manufacture of refined petroleum products		
Ten "Manufacture of refined petroleum products" most consumer sectors	Monetary flow (million euros)	% of the total flow of this product
Manufacture of refined petroleum products	2 744	9,9%
Freight transport by road or via pipelines	2 579	9,3%
Manufacture of basic organic chemicals	2 279	8,2%
Wholesale trade and commission trade	1 878	6,8%
Retail trade, repair of personal and household goods	1 258	4,5%
Agriculture, hunting, trapping and related service activities	1 237	4,5%
Air transport	912	3,3%
Civil engineering works	876	3,2%
Public administration and defence	759	2,7%
Construction and installation of buildings	685	2,5%

Table 3.12: Ten most consumer sectors of crude petroleum and gas extraction

The fact that "Air transport" also belongs to the top ten of "Manufacture of refined petroleum products" consumers" could seem surprising when having in mind that the share of tonnes or tkm transported by air is small. Nevertheless, "Air transport" also include passenger travels made by plane which are often used for distances less than 1 000 km, when the emission factor is the highest, 4,7 times greater than the road factor for transportation of goods.

One can also notice that the petroleum sectors consumes output of its own sector. This is probably related to the production pattern of the sector though no policy recommendations can be done on this special point without a closest examination by the means of a physical LCA for example. However, this internal loop shows that reducing dependency on petroleum products will benefit from a double reduction. As such, table 3.12 shows that modal transfer from road and air to low carbon intensive transporation mode will reduce the reliance on the "Manufacture of refined petroleum products", a not so efficient sector since 9,9 % of its output need to be reused as input. This transfer will have a double impact: the reduction of the direct emission from the transportation sector and the reduction of indirect emissions associated with the production and transportation of petroleum products to refineries.

Concerning the sector "Extraction of crude petroleum and natural gas", one should not forget that extraction of gas is included. This explains the fact that 22 % of the flows correspond to the "Gas, steam and hot water supply" sector. Reduction in gas consumption could then be made through a better use of the water heating systems by households or the replacement of current heating systems by solar based ones. [25]

Manufacture of refined petroleum products	
Ten sectors with highest direct purchase share of "Manufacture of refined petroleum products"	% of direct purchase
Mining of metal ores	14,0%
Freight transport by road or via pipelines	12,0%
Manufacture of basic organic chemicals	11,7%
Manufacture of refined petroleum products	7,0%
Air transport	5,8%
Water transport	5,0%
Fishing, fish farming and related service activities	4,6%
Activities of travel agencies and tour operators; tourist assistance activities n.e.c.	2,5%
Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction	2,4%
Other mining and quarrying	2,3%

Table 3.13: Ten sectors with highest direct purchase share dedicated to refined petroleum products

Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction	
Ten sectors with highest direct purchase share of "Extraction of crude petroleum;etc"	% of direct purchase
Manufacture of refined petroleum products	45,3%
Gas, steam and hot water supply	31,7%
Manufacture of basic inorganic chemicals	21,2%
Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction	8,7%
Sale, maintenance and repair of motor vehicles and motorcycles, retail sale of automotive fuel	1,4%
Civil engineering works	0,26%
Manufacture of pulp, paper and paperboard	0,18%
Casting of metals	0,17%
Construction and installation of buildings	0,14%
Wholesale trade and commission trade	0,12%

Table 3.14: Ten sectors with highest direct purchase share dedicated to crude petroleum and gas extraction

In term of direct purchase, the assessment of "Manufacture of refined petroleum product" is less dramatic since only 7 % of the direct purchase are dedicated to the internal loop.
Nevertheless, refined petroleum products still represents a high share direct purchase of the based transportation mode such as road, air and water, between 5 and 12 %. This expressed a high sensitivity of these modes to the oil price.

Since 2004, the oil price has been raising from 40 $ the barrel to 130 $ the barrel. [32] Firstly, this increase has a huge economical impact with an increase in price for special sectors as agriculture and freigh transport via road. Consequently, road transporters and farmers started protestations against the increase in price. [33]

This demonstrates the new fragility of an oil based economy and the problem in term of national security generated by a high dependency on foreign resources such as oil. When the oil crisis took place in 1973, France decided to launch an ambitious nuclear program for the national security reason described above. In conclusion, this new oil crisis makes the shift from road to rail, waterway and maritime transportation even more attractive and a combination of road with those modes will be a smooth way to profundly change freight transportation by road while avoiding social conflicts. [4]

3.3.2 Mining of coal and lignite; extraction of peat

Mining of coal and lignite; extraction of peat		
Ten "Mining of coal and lignite; extraction of peat" most consumer sectors	Monetary flow (million euros)	% of the total flow of this product
Manufacture of coke oven products and processing of nuclear fuel	9	18,9%
First processing of iron and steel	7	14,3%
Public administration and defence	3	6,0%
Wholesale trade and commission trade	1,3	2,7%
Gas, steam and hot water supply	1,1	2,2%
Manufacture of basic inorganic chemicals	0,9	1,9%
Construction and installation of buildings	0,9	1,9%
Manufacture of ceramic goods, products for construction purposes and other non-metallic mineral products	0,7	1,4%
Manufacture of structural metal products	0,7	1,4%

Table 3.15: Ten most consumer sectors of coal

Half of the "Mining of coal and lignite; extraction of peat" is consumed by the top ten sectors and one third by "Manufacture of coke oven products and processing of nuclear fuel" and "First processing of iron and steel". As such, considering the high emission factors associated with indirect consumption of coal, efforts should be made to reduce the dependency of these two sectors on coal. (see figure 3.13)

Mining of coal and lignite; extraction of peat		
Ten "Mining of coal and lignite; extraction of peat" most consumer sectors	Monetary flow (million euros)	% of the total flow of this product
Manufacture of coke oven products and processing of nuclear fuel	9	18,9%
First processing of iron and steel	7	14,3%
Public administration and defence	3	6,0%
Wholesale trade and commission trade	1,3	2,7%
Gas, steam and hot water supply	1,1	2,2%
Manufacture of basic inorganic chemicals	0,9	1,9%
Construction and installation of buildings	0,9	1,9%
Manufacture of ceramic goods, products for construction purposes and other non-metallic mineral products	0,7	1,4%
Manufacture of structural metal products	0,7	1,4%

Table 3.16: Ten sectors with highest direct purchase share dedicated to coal mining

The main outcome of table 3.16 is that for each of the ten sectors, "Mining of coal and lignite; extraction of peat" represents an incredibly low share of direct purchase compared to the emission driven. This point could justify a carbon tax for this particular sector since the increase in price will not provide huge changes in financial budgets. (see figure 3.14)

3.3.3 The food sectors

Five of the ten most emission intensive imported goods are related to food products. As such they represent 11 % of the total emission driven by the transportation of goods and 0,7 % of total GHG emissions associated with

French household consumption. The shares respectively reach 29 % and 1,9 % if one adds the domestic transportation of these goods. This demonstrates the importance of these sectors whose main consumers and direct shares are presented in appendix G.

The analysis of these data show that the direct consumers of food are either food sectors or services sectors dedicated to people such as health, education, hotel and restaurants. Actually, the supply chain summarized in figure 3.12 shows a three level supply chain. At the basis is the "Agriculture sector" of which 45 % of the ouput goes to the production of meat, dairy products and other food products. Then, at the second level, the food manufactures along with the manufacture of beverages exchange their product (17 % of their output) and supply the third level of the supply chain, made of the three consumers: health, education and restaurants (19 % of their output).

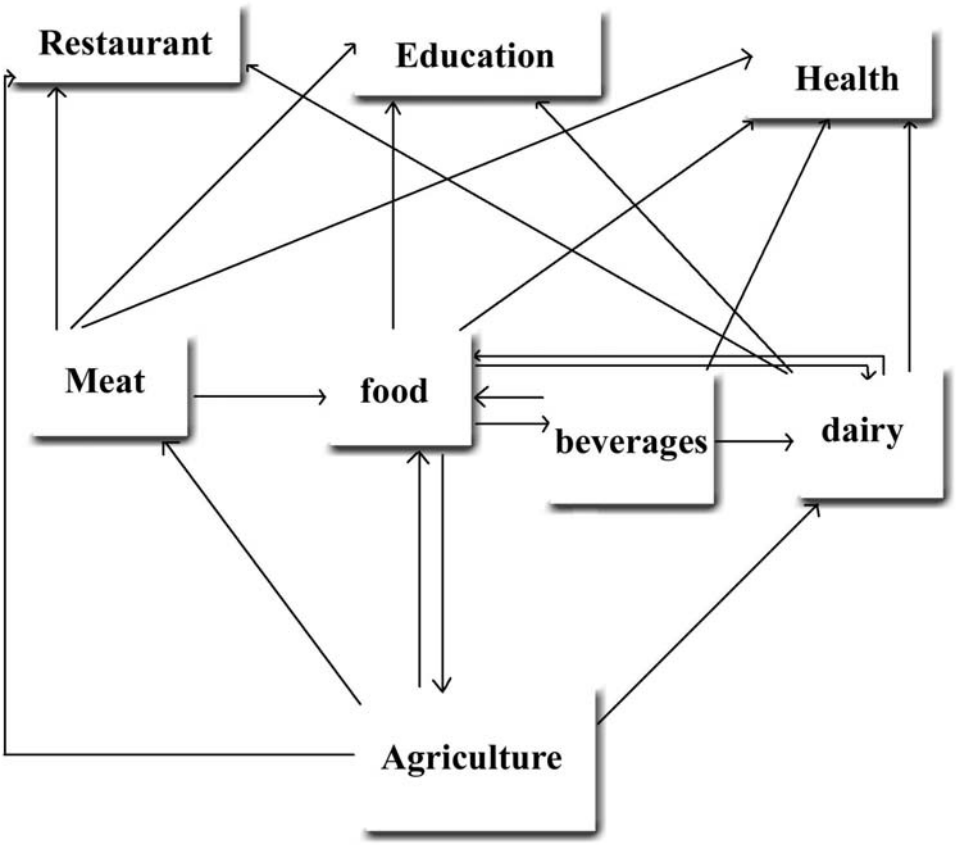

Figure 3.12: The supply chain of food products

In term of direct purchase, the conclusion remains the same, the flow between the food sectors representing 10 % of their purchase whereas the purchase of food products by restaurant, health and education institutions represents 5 % of their direct purchase.

An effective way of reducing emissions from the food sectors would be to concentrate efforts on the following points:

- In the case of food product, the final consumers are either private (hotel and restaurant) or collective (heath and education institution) consumers. There is a real difficulty to obtain emission reduction from a private consumption all the more since restaurant is perceived as a leisure activity. On the opposite, effective efforts can be made by the government to ensure an environmental friendly diet in schools and hospitals where they have a direct decision on the purchase.

- The obesity in France is increasing and at the current rate, 20 % of the French population might be obese in 2020 [34]. This national health problem comes from unbalanced diet and lack of physical activity. a part of these unbalanced diet is due to the overconsumption of meat products. Consequently, reduction in meat consumption will provide benefits both in improving health and reducing CO_2 emissions. In conclusion, it appears that the government should encourage an environmental and heath friendly diet in schools and hospitals and provide an education on food and its consequences on health and the environment.

- At the basis of the food chain lies the agriculture sector already responsible for 11 % of the total emission driven by the transportation of goods associated with French household consumption (domestic transportation included). When the emissions from production are added, the share of the sector grows to 34 % of the total indirect GHG emissions associated with French household consumption as shown on figure 3.2. So, future studies should study in detail this sector in order to find the most emittive consumption and production patterns and propose evolutions towards an agriculture based on practices respectful of the environment and human health.

3.3.4 Manufacture of pharmaceuticals, medicinal chemicals and botanical products

Manufacture of pharmaceuticals, medicinal chemicals and botanical products		
Ten "Manufacture of pharmaceuticals, medicinal chemicals and botanical products" most consumer sectors	Monetary flow (million euros)	% of the total flow of this product
Non-Market Human health	1 998	10,4%
Market Human health	1 757	9,1%
Agriculture, hunting, trapping and related service activities	658	3,4%
Wholesale trade and commission trade	647	3,4%
Investigation and security activities, industrial cleaning and miscellaneous business activities n.e.c.	498	2,6%
Veterinary activities	442	2,3%
Social work activities	266	1,4%
Manufacture of other food products	252	1,3%
Market Research and development	246	1,3%

Table 3.17: Ten most consumer sectors of medicinal products

35 % of the "Manufacture of pharmaceuticals, medicinal chemicals and botanical products" are consumed by the top 10 sectors ; and without surprise, animal, people healthcare and agriculture together with other food products are the main contributive sectors.

Manufacture of pharmaceuticals, medicinal chemicals and botanical products	
Ten sectors with highest direct purchase share of "Manufacture of pharmaceuticals, medicinal chemicals and botanical products"	% of direct purchase
Veterinary activities	22,9%
Manufacture of pharmaceuticals, medicinal chemicals and botanical products	17,7%
Non-Market Human health	3,9%
Market Human health	2,9%
Market Research and development	2,1%
Manufacture of grain mill products, starches and starch products, prepared animal feeds	1,5%
Social work activities	1,3%
Manufacture of agro-chemical products, paints and other chemical products	1,1%
Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction	1,00%
Manufacture of basic organic chemicals	0,99%

Table 3.18: Ten sectors with highest direct purchase share dedicated to medicinal products

In term of direct purchase shares, two sectors are particularly dependant on pharmaceuticals, medicinal chemicals and botanical products: "veterinary activities" and "Manufacture of pharmaceuticals, medicinal chemicals and botanical products".
Firstly, This means that though the internal loop is small, pharmaceuticals, medicinal chemicals and botanical products are among the expensive input products purchased by the sector. Then, in term of emission reduction, a carbon tax would mean a high increase in prices for vetinary activities and relatively less for human healthcare.

Nevertheless, healthcare as education and food supply is a fundamental need for every human being and as such, increase in prices in these sectors must be analysed under the scruting eye of social equity.

3.3.5 Manufacture of furniture

Manufacture of furniture		
Ten "Manufacture of furniture" most consumer sectors	Monetary flow (million euros)	% of the total flow of this product
Public administration and defence	386	8,0%
Manufacture of furniture	297	6,1%
Manufacture of parts and accessories for motor vehicles	199	4,1%
Non-Market Human health	188	3,9%
Hotels and restaurants	164	3,4%
Retail trade, repair of personal and household goods	131	2,7%
Market Human health	130	2,7%
Manufacture of aircraft and spacecraft	128	2,6%
Wholesale trade and commission trade	111	2,3%

Table 3.19: Ten most consumer sectors of furniture

36 % of "Manufacture of furniture" are consumed by the top ten sectors, public administration and healthcare being the main consumers. One can also notice an internal loop of 6 % which is also found in table 3.20 concerning direct purchase share. Nevertheless, the direct purchase share of "Manufacture of furniture" remains low for all sectors.

Manufacture of furniture	
Ten sectors with highest direct purchase share of "Manufacture of furniture"	% of direct purchase
Manufacture of furniture	2,5%
Manufacture of motor vehicles, bodies and trailers	1,7%
Manufacture of parts and accessories for motor vehicles	0,68%
Manufacture of railway and tramway locomotives and rolling stock	0,40%
Non-Market Human health	0,37%
Building and repairing of ships and boats	0,35%
Manufacture of aircraft and spacecraft	0,35%
Motion picture, video, radio and television activities	0,34%
Manufacture of electrical equipments and apparatus n.e.c.	0,32%
Manufacture of optical instruments, photographic equipment, watches and clocks	0,31%

Table 3.20: Ten sectors with highest direct purchase share dedicated to furniture

Reducing emissions from the manufacture sectors could then be made the following ways:

- Buying local: actually, only 56 % of the furniture are domestically produced and though some furniture designs only exist abroad, there is here a possibility to increase the domestic share and this way reduce the tkm driven and emission associated.

- Furniture are transported either by road or plane, the two most carbon intensive transportation mode. This is rather dramatic when considering 60 % of the emission of imported furniture take place inside Europe

and 50 % in the EU15, the rest being mainly covered by Asia, 18 % and other America, 12 %. Once again, this demonstrates the urgent need for shifting from road and air transportation to low carbon intensive transportation modes.

3.4 The effects of a carbon tax

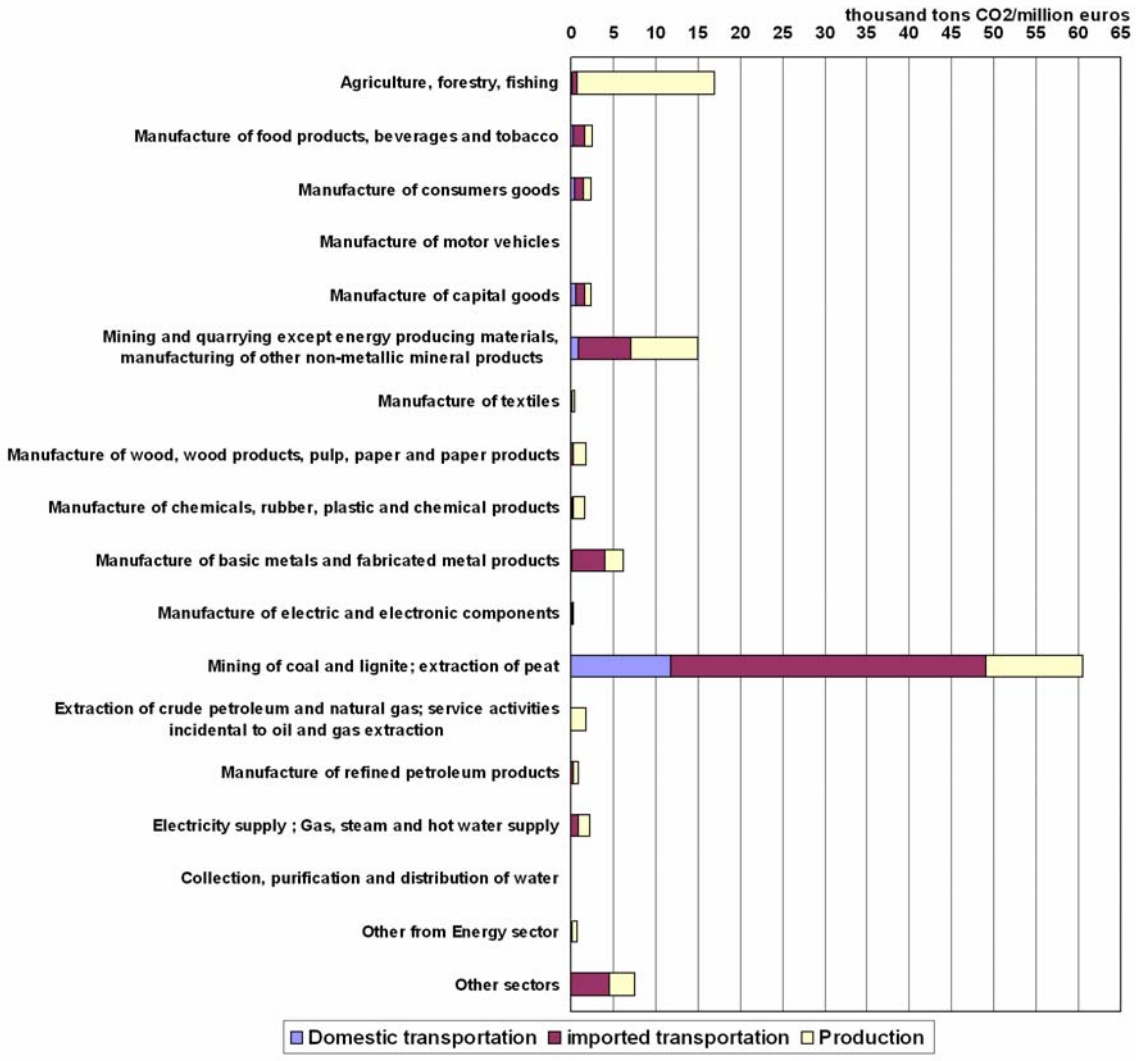

Figure 3.13: The direct eco-efficiencies factors related to indirect consumption of households of 18 sectors

Figure 3.13 presents the eco-efficiencies factors related to indirect consumption of households for 18 sectors in term of kg CO2 per euro. In fact, these sectors are those of figure 3.2 with "manufacture of intermediate goods" and other energy sectors presented on a more disaggregated level.

Three sectors are low efficient and efforts to reduce emission should focus on them:

- "Agriculture, forestry, fishing": 96 % of the emission per euro produced is due to production. So, for this sector, efforts to increase eco-efficiency should focus on production patterns.
  Nevertheless, one can notice that 85 % of the 4 remaining percent are realised by imported transportation. So, if only focusing on emission reduction from transportation, efforts should be made on the import share.

- "Mining and quarrying except energy producing materials, manufacturing of other non-metallic mineral products": the share between transportation is more equilibrate for this sector: 53 % for production against 47 % for transportation. Nevertheless, one can note that 87 % of the transportation share comes from imports. So, if only focusing on emission reduction from transportation, efforts should be made on the import share.

- "Mining of coal and lignite; extraction of peat": Transportation represents the main share of the emission per euro, 81 % against 19 % for production. Of these 81 %, 76 % are related to importation of goods. Once again, it appears that when focusing on emission reduction from transportation, efforts should be made on the import share.

Finally, it should be noted that coal consumers are siderurgy manufactures and coal power plants for the production of electricity and though projects of clean coal power plant are under study, the emissions of this sector concentrates in the transportation sector, 81 % against 19 % for the production phase. As a result, efforts to reduce emissions should focus on the transportation sector. In fact, 63 % of the coal tons consumed by French households are produced domestically and 38 % are imported, but in term of emission associated with the transportation of those tons, importation raises up to 88 % which demonstrates that France is currently supplied by far away countries. Actually, of the 6,4 millions imported tons of coal associated with the French household consumption, 29 % comes from Europe, 23 % from Oceania, 17 % from other America, 14 % from Africa, 11 % from north America and 7 % from Asia. Inside Europe, the main contributor is

the new ten countries of the European Union, 12 %. But when it comes to the GHG emission, the share of Europe is only 10 % compared to 38 % for other America, 21 % for Oceania and 14 % for Africa. As such, shifting to european or local coal mines would seem a way to reduce emissions.

Nevertheless, this might not be the case since inside the EU 15, 69 % of the coal tons are transported by road whereas 98-100 % of the tons from other America, Oceania and Africa associated with the French household consumption are transported via maritime and water ways which emit respectively 40 times and 6 times less carbon dioxide per tonne-kilometer transported than road transportation. So, there is a trade-off on which future studies should focus between the reduction of tonne-kilometers provided by shifting to local sources of coal and the reduction in carbon efficiency associated with shifting from water to road transportation.

In conclusion, figure 3.13 emphazises a low eco-efficiency associated with transportation of imported goods. So, emission reduction through a carbon tax for example will be an option to take into account in order to enforce better eco-efficiency by increasing the cost.

Figure 3.14 presents the increase in cost due to a 50 euros per ton CO_2 emitted tax.

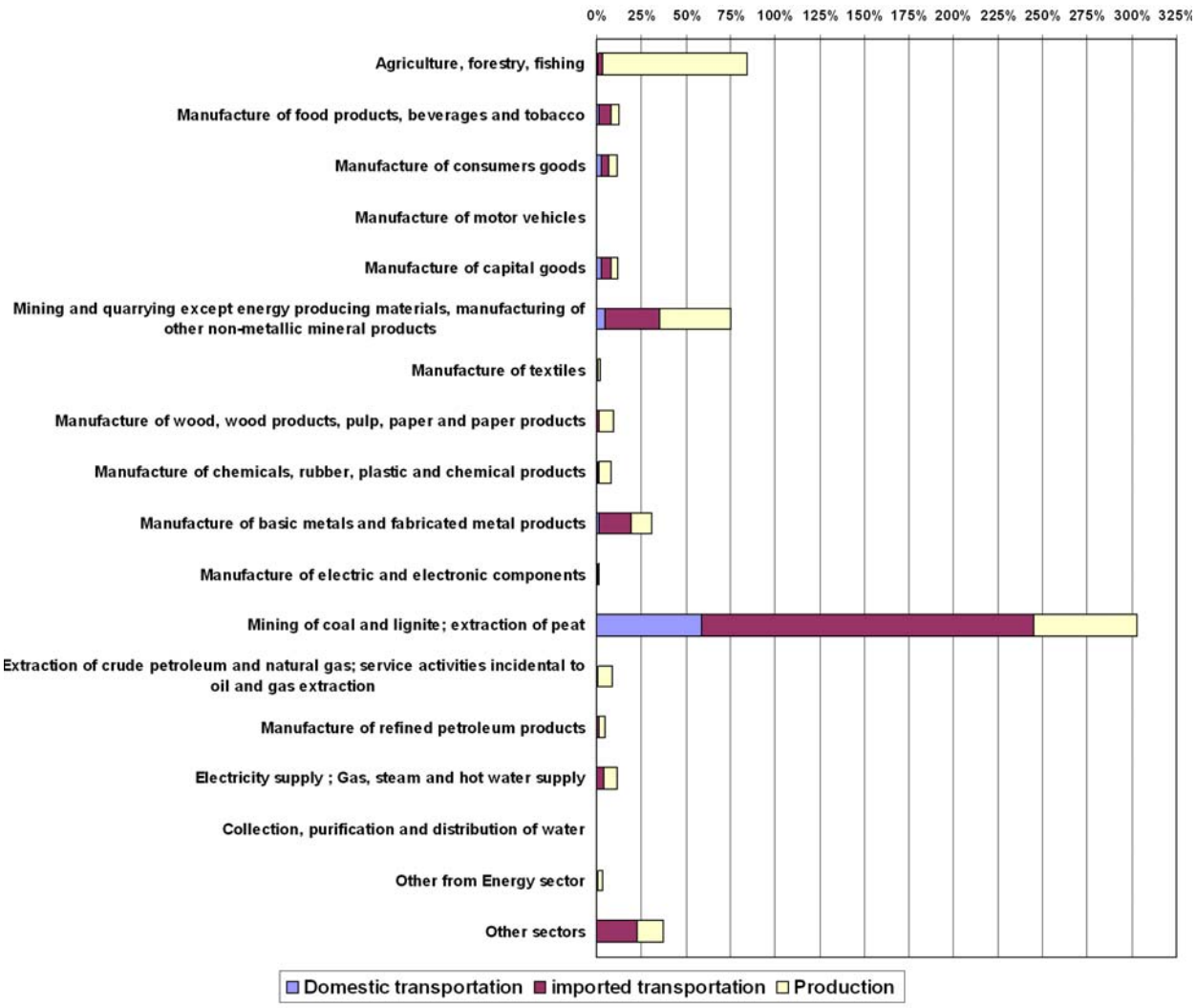

Figure 3.14: Increase in cost due to a 50 Euros per CO_2 tons tax

Firstly, the advantage of the tax is to keep track of the eco-efficiency factor. Actually, the increase in cost is predominant in the same sectors as in figure 3.13.

Then, the tax does not seem a efficient way to reduce emission for all sectors. For example, in the recent atmosphere of food price rising, an increase in cost of 85 % in the agriculture sector is not acceptable. This would particularly be harmful to the poors and bad for exportations, making French agriculture lose its competitiveness. Nevertheless, the agriculture sector is mainly european since 76 % of the imported tons come from Europe and 69 %

from the EU 15 alone. In term of non-european countries, other America is the only signficant country representing 11 % of the imported tons.

In fact,the best solution will be to only tax transportation.
This reduces the increase in cost in the agriculture and manufacture of food to respectively 3,5 % and 8,3 %. In the meantime, a tax concerning only transportation gives an increase in price of 250 % for "Mining of coal and lignite; extraction of peat" and 36 % for "Mining and quarrying except energy producing materials, manufacturing of other non-metallic mineral products". In conclusion, a tax on transportation will be really efficient in isolating the coal sector, providing high increase in price for it meanwhile not giving high increase in other sectors.

Production should be addressed on another level. Coming back to figure 3.2, one can see that domestic production is at the core of the agriculture, hunting and forestry emission level. Therefore, technical or logistic improvements are needed. Perhaps, a shift in consumption pattern can be of interest if the high emission level is linked to a natural cause such as methane emission from cows. As an example, the food-mile study made in the US [13] shows that it was more efficient to consume less red meat than buying local, meaning that as in the case of France, production is the main emission driver. Comparing results, the share in emission associated with production is even larger in France than in the US since for france, 97 % of the CO_2 emissions are associated with production compared to 83 % in the US. As a result, the interest of reducing our consumption of red meat and dairy products, two products having their main emission associated with the production phase [13] appears even higher in France than in the US.Nevertheless, a more detailed study on food products should be done to provide further understanding of a change in consumption pattern.

Overall, food policies should promote health through a balanced diet without overconsumption of meat and ensure best environmentally practices in the production phase.

Chapter 4

Conclusion

The average French household emits 22,4 tons. Of these, 7 % comes from the transportation of goods, 40 % being imported and 60 % domestically produced. The analysis shows a distinction between European Union and the rest of the world. The EU 15, France included, represents 92 % of the tons consumed by French households and 78 % of the CO_2 emissions associated with their transportation. They are mainly transported by road which emits 40 times more carbon dioxide per tonne-kilometer transported than maritime transportation, the main mode used for the transportation of goods coming from non-european countries.

Consequently, the analysis demonstrates the potential emission reduction associated with shifting from road to other low carbon intensive terrestrial mode such as rail and waterways, up to 1 % of total emissions driven by household consumption and 15 % of those associated with the corresponding transportation of goods. In term of infrastructure, this would mean to develop combined transportations by improving the rail and waterway networks, notably connections with the border countries of France which are the main trade partners (Germany, Italy, Belgium, Luxembourg, Netherlands and Spain).

Furthermore, the study shows that the main contributing sectors in term of emission are petroleum related sectors, food sectors and coal sector. Consequently, the study provides policy recommendations for reduction in these sectors.

Firstly, the main emissions associated with petroleum sectors come from the production phase and refined petroleum products are mainly consumed by the road and air transportation sectors. This implies that France should reduce its dependency on petroleum products, a foreign energy source. This could be done by shifting from road transportation to rail an important share

of the tonne-kilometers driven inside the EU 15 and develop low carbon intensive alternative fuels for the non shiftable share of road transportation.

Then, concerning the emission associated with food sectors, they mainly come from the production phase made of a three level supply chain.

At the basis lies the agriculture sector whose emissions are concentrated in the production phase. A carbon tax of 50 euros per ton CO_2 will provide a 85 % increase of cost for this sector. As a result, a carbon tax for this partcular sector would be particularly unpopular and compete with the notion of social justice since a huge increase in cost will particularly be harmful to the poors. The reduction in the agriculture sector should then be based on the development of the best practices and a change in consumption pattern which might be driven by a carbon tax adapted to particular products, for example meat and dairy products.

The second level of the food supply chain concerns manufature sectors of beverages, dairy products and other food products along with the processing of meat products. In fact, meat represents as much as 5 % of the total emission associated with transportation of goods for French household consumption and 1 % of the total emissions associated with French household consumption. As obesity increases in France, concerns about heath should correspond to a shift in consumption pattern, meat and dairy products being less consumed. Nevertheless, transportation already accounts for 34 % of the indirection emission associated with the consumption of meat by French households and as such, emission reduction are achievable in this particular sector. Actually, of these 34 %, 20 % corresponds to domestically produced meat of which 84 % are transported by road and 14 % to imported meat of which 69 % are transported via maritime transportation against 23 % for the 40 times more carbon intensive transportation mode, road.

The main consumers of the food products are hotel and restaurant, health and education institutions. As restaurant corresponds to a leisure and a personal activity, reduction in emission would difficultly be achievable in this sector. This not the case for public institutions where the goverment can ensure a balanced and environmentally friendly diet by reducing consumption of meat, fighting against obesity, buying local and from lower carbon intensive agriculture (organic food).

Finally, it should be noted that coal consumers are siderurgy manufactures and coal power plants for the production of electricity and though projects of clean coal power plant are under study, the indirect emissions of this sector concentrates in the transportation sector, 81 % against 19 % for the production phase.

As a result, efforts to reduce emissions should focus on the transportation sector. In fact, 63 % of the coal tons consumed by French households are produced domestically and 38 % are imported, but in term of emission associated with the transportation of those tons, importation raises up to 88 % which demonstrates that France is currently supplied by far away countries. Actually, of the 6,4 millions imported tons of coal associated with the French household consumption, 29 % comes from Europe, 23 % from Oceania, 17 % from other America, 14 % from Africa, 11 % from north America and 7 % from Asia. Inside Europe, the main contributor is the new ten countries of the European Union, 12 %. But when it comes to the GHG emission, the share of Europe is only 10 % compared to 38 % for other America, 21 % for Oceania and 14 % for Africa. As such, shifting to european or local coal mines would seem a way to reduce emissions.

Nevertheless, this might not be the case since inside the EU 15, 69 % of the coal tons are transported by road whereas 98-100 % of the tons from other America, Oceania and Africa associated with the French household consumption are transported via maritime and water ways which emit respectively 40 times and 6 times less carbon dioxide per tonne-kilometer transported than road transportation.

So, there is a trade-off on which future studies should focus between the reduction of tonne-kilometers provided by shifting to local sources of coal and the reduction in carbon efficiency associated with shifting from water to road transportation.

In conclusion, many possibilities exist to provide reduction of the emissions associated with the transportation of goods consumed by French households: shift in consumption pattern, shif to local source ; but they all urge for an increase in the carbon efficiency of the transportation inside the EU 15 and mostly inside France and its border countries which are French main trade partners. Actually, road is currently the main transportation mode used in these countries ; and an ambitious policy of transfer to rail, water or maritime ways is needed through the development of the appropriate infrastructure and the combination of the advantages of the different modes, flexibility of the road transporation associated with mass and environmentally friendly transportation of rail, waterway and maritime modes.

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Appendix A

Description of the SITRAM data base

This appendix describes the SITRAM database and list the products missing in the analysis.

A.1 Description of the SITRAM database

The SITRAM database is developped by the MEDAD and concerns the transportation of goods.

The goods are classified according to the statistic nomenclature of transport whose most disaggregated level (176 products) is shown in appendix.

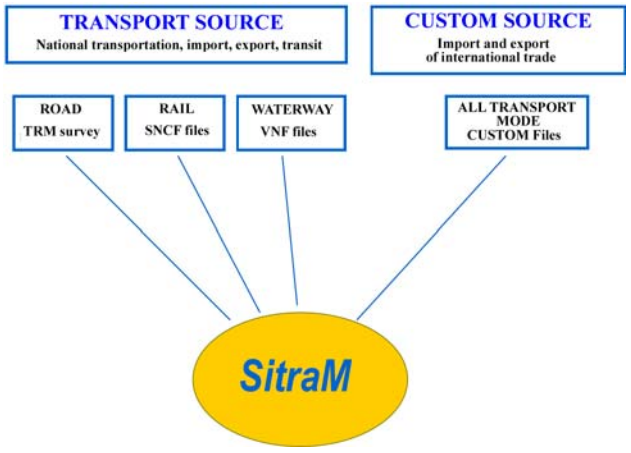

Figure A.1: Structure of the SITRAM database

There is two sources of data available in the SITRAM Database:

- Transport source for which the vehicle transporting the goods is tracked down
- Custom source for which the goods is tracked down

The differentiation between the two sources is important since the definitions of national and international transportation differ according to the source.

Actually, if the vehicle is tracked down, the national transportation corresponds to a vehicle staying on the national territory whereas international transportation happens when the vehicle goes across the border. On the other hand, if the goods are tracked down, international transportation concerns all goods designated to imports or exports.

For this thesis, the analysis of the consumption pattern being the main interest, the national transportation concerns goods produced in France whereas international transportation concerns goods imported.

As such, the Custom source is the one to use to describe international transportation and the Transport Source the one to descibe national transportation, assuming that vehicles delivering goods from France to France never go accross the border.

Nevertheless, according to the SITRAM database documentation, a risk of double counting can occur when compiling data from the two different sources. For example, a good transported by truck from Paris to Le Havre, unloaded in the port and then loaded on a boat to be exported to another country will be taken into account both in the Transport Source as natioanal road transportation and in the Custom source as maritime transportation.

As only imports are of interest here, the example given previously for exportation is of no appliance. Besides, the data for imports are given in tons and the transformation in tkm is done manually by multiplying the tons entering the French territory by the distance between the area of production and the region of France where the good imported is consumed.

The only risk of double counting would be for goods domestically produced and dedicated to export ; but this can be taken as a part of national transportation since the good is first loaded and unloaded in France where it impacts the infrastructure even if the consumption occured abroad. The differentiation betwen consumption would be then a result of a differentiation between the final demands of the IO model.

TRM file TRM stands for Transport Routier de Marchandises (Road Transportation of Goods). Data consist in an annual survey which concerns motor vehicles registered in France since 1996. In 2002, in order to be consistant with an universal definitionof heavy trucks, it was decided a new field compared to the 1996 one. The differents between the two fields were found small.

- trucks whose Total Permitted Weight (PTAC in French) is superior to 3,5 tons and inferior to 32,6 tons whatever the liveload is and whose age, considering difference between the year of first circulation and the year of the survey, is inferior or equal to 15 years old. Before the field was: truck with at least 3 tons liveload, age inferior to 15 years old and maximum TPW of inferior to 36,6 tons.
- road tractors whose TPW is superior or equal to 5 tonnes and inferior or equal to 44,5 tons and whose age, considering difference between the year of first circulation and the year of the survey, is inferior or equal to 15 years old. Before the field was: truck age inferior to 15 years old and maximum TPW between 4,9 tons and 44,6 tons.

As explained in Section E.2, the light vehicles whose TPW is inferior to 3,5 tons are not taken into account in the analysis. This is a part of the uncertainties introduced by the utilisation of the SITRAM database.

The transport is classified according to the nature of the transporation made by the vehicle concerned by the enquiry:

- **transport for other account**: Paid transportation of goods for a tierce account.
- **transport for own account**: all transportation which is not accounted as transport for other account.

The survey is based on a sample of vehicle followed during one week. The transportation is then mesured in tons and tkm and the sample error is also reported. (see Section E.2)

SNCF file SNCF stands for Société Nationale des Chemins de Fer (National RailWay Society). Data describe national and international transportation realized by complete wagon.
Weapon and ammunition transportation is exluded as parcels transporation made by the SERNAM.

Since 1993, the file used in SITRAM database is an exhaustive file whereas before, SITRAM gave results based on a sample and a exhaustive file for heavy transportation.
Up to 1998, the distinction between national and international transportation was made by tracking down the goods: a good loaded and unloaded in France but circulating with a international way bill was considered as international transportation. Now it is possible to define the national transportation by tracking down the wagons in coherence with TRM and VNF files.
This file is the one used in the thesis, tracking the goods being done by using the Custom source.

VNF file VNF stands for Voies Navigables de France. Data describe national and international transportation for own and other accound made under French and foreign flags.
Results include internationally regulated traffic on the Rhine and the Moselle, which means interior and internaional traffic on the hine between Basle and Lauterbourg and on the Moselle between Metz and the border, excluding traffic on this two ways coming from or destinated to other waterways.
This trafic is low in case of interior transportation.

The overall documentation on the Sitram database is available on the ministry website [18].

A.2 Missing data and hypothesis made for the analysis

The following tables present the goods for which an error or a personal judgement had to be made. They are given in the orginal nomenclature of the Sitram database, the NST one along with the corresponding NES sectors. As shown by the tables, there are three type of errors or biases:

- absence from domestic data: Five products are missing in the domestic database. As a result, the results might not be as exhaustive as wanted. The Uncertainties related to the missing products is addressed in appendix E.2.
- absence from import data: Eight products are missing in the import database. Five of them are the same as the one missing from domestic database. The Uncertainties related to the missing products is addressed in appendix E.2.
- hypothesis: Seven product were missing from the correspondance table between CPA 2008 and NST. As a resultn hypothesis were made which stands as follows:
  - Mine wood (code NST 52): same Structure as code NST 51
  - Steel hoop and strip, tinplate (Non-ECSC) (code NST 546): same structure as code NST 545
  - Phosphates Salt, Crude, Natural (code NST 713): same structure as 711
  - Dephosphorisation scories (code NST 721): same structure ascode NST 711
  - old package (code NST 991): the NST sector 991 matches perfectly with sector 38 of CPA 2008 nomenclature
  - old construction firms' material, old circus car and materials (code NST 992): the NST sector 992 matches perfectly with sector 38 of CPA 2008 nomenclature.
  - Moving out furniture (code NST 993): the NST sector 993 matches perfectly with sector 49 of CPA 2008 nomenclature.

SITRAM Code	NES code	Nature of uncertainty
052	GA01	Hypothesis + absent from Import Data
	GA02	
	GN22	
	GN23	
	GN24	
	GN25	
	GN32	
	GN33	

SITRAM Code	NES code	Nature of uncertainty
327	GC31	Absent from Import Data
	GC32	
	GE11	
	GE12	
	GE13	
	GE14	
	GE32	
	GF12	
	GF21	
	GF22	
	GF23	
	GF31	
	GF32	
	GF33	
	GF41	
	GF42	
	GF43	
	GF44	
	GF45	
	GF46	
	GF51	
	GF52	
	GF53	
	GF56	
	GF61	
	GG11	
	GG14	
	GG15	
	GG2A	
	GG2B	
	GN34	

SITRAM Code	NES code	Nature of uncertainty
330	GC31	Absent from Import Data
	GC32	
	GF41	
	GF42	
	GF43	
	GF44	
	GG11	
	GG12	
	GG14	
	GG15	
	GG2A	
	GG2B	

SITRAM Code	NES code	Nature of uncertainty
452	GC41	Absent from Import and Domestic Data
	GC42	
	GC43	
	GE21	
	GE22	
	GF11	
	GF51	
	GF52	
	GF53	
	GF54	
	GF55	
	GG13	
	GG14	
	GG15	

SITRAM Code	NES code	Nature of uncertainty
467	GB01	Absent from Import and Domestic Data
	GB02	
	GB03	
	GB04	
	GB05	
	GC31	
	GC32	
	GC41	
	GC42	
	GC43	
	GF41	
	GF42	
	GF43	
	GF44	
	GG14	
	GG15	

SITRAM Code	NES code	Nature of uncertainty
546	GC41	Hypothesis
	GC42	
	GC43	
	GE21	
	GE22	
	GF51	
	GF52	
	GF53	
	GF55	
	GF56	
	GG14	
	GG15	

SITRAM Code	NES code	Nature of uncertainty
622	GF12	Absent from Import and Domestic Data
	GG11	

SITRAM Code	NES code	Nature of uncertainty
711	GB01	Absent from Import and Domestic Data
	GB02	
	GB03	
	GB04	
	GB05	
	GC31	
	GC32	
	GC41	
	GC42	
	GC43	
	GF41	
	GF42	
	GF43	
	GF44	
	GG14	
	GG15	

SITRAM Code	NES code	Nature of uncertainty
713	GF12	Hypothesis
	GG11	

SITRAM Code	NES code	Nature of uncertainty
721	GF12	Hypothesis
	GG11	

SITRAM Code	NES code	Nature of uncertainty
831	GB01	Absent from Import and Domestic Data
	GB02	
	GB03	
	GB04	
	GB05	
	GC31	
	GC32	
	GC41	
	GC42	
	GC43	
	GF41	
	GF42	
	GF43	
	GF44	
	GG14	
	GG15	

SITRAM Code	NES code	Nature of uncertainty
991	GC12	Hypothesis
	GC31	
	GC32	
	GE11	
	GE12	
	GE13	
	GE14	
	GE32	
	GF12	
	GF21	
	GF22	
	GF23	
	GF31	
	GF32	
	GF33	
	GF41	
	GF42	
	GF43	
	GF44	
	GF45	
	GF46	
	GF51	
	GF52	
	GF53	
	GF56	
	GF61	
	GG14	
	GG15	
	GG2A	
	GG2B	
	GN34	

SITRAM Code	NES code	Nature of uncertainty
992	GC12	Hypothesis
	GC31	
	GC32	
	GE11	
	GE12	
	GE13	
	GE14	
	GE32	
	GF12	
	GF21	
	GF22	
	GF23	
	GF31	
	GF32	
	GF33	
	GF41	
	GF42	
	GF43	
	GF44	
	GF45	
	GF46	
	GF51	
	GF52	
	GF53	
	GF56	
	GF61	
	GG14	
	GG15	
	GG2A	
	GG2B	
	GN34	

SITRAM Code	NES code	Nature of uncertainty
993	GK01	Hypothesis
	GK02	
	GK03	

Appendix B

Region

Actually, since 1790, France has been divided into 95 metropolitan départements and four overseas départements.

Each département is run by its own local council, the "conseil général" which has its headquarters in the principal town ("le chef-lieu du département").

Every départment has a code number which appears as the first two figures of postcodes and, which is more interesting in our case, the last two figures on vehicle registration plates.

The thesis focuses on the metropolitan territory meaning that overseas départements (DOM) and overseas territories (TOM) are considered as foreign countries. This approach is constistent with the one taken by the MEDAD. The following tables show the repartion of the metropolitan départements by region and the SITRAM code associated. Then, figure B.1 allows the reader to situate each region on the French map.

Regions	**Département**	**Regional code in SITRAM database**
île de France	Paris (75) Seine-et-Marne (77) Yveline (78) Essone (93) Hauts-de Seine (92) Seine-Saint-Denis (93) Val-de-Marne (94) Val-d'Oise (95)	11
Champagne-Ardenne	Ardennes (08) Aube (10) Marne (51) Haute-Marne (52)	21

Table B.1: Breadown of French regions in départements and their SITRAM code (1/3)

Regions	**Département**	**Regional code in SITRAM database**
Picardie	Aisnes (02) Oise (60) Somme (80)	22
Haute-Normandie	Eure (27) Seine-Maritime (76)	23
Centre	Cher(18) Eure-et-Loir (28) Indre (36) Indre-et-Loire (37) Loir-et-Cher (41) Loiret (45)	24
Basse-Normandie	Calvados (14) Manche (50) Orne (61)	25
Bourgogne	Côte-d'Or(21 Nièvre (58) Saône-et-Loire (71) Yonne (89)	26
Nord-Pas-de-Calais	Nord (59) Pas-de-Calais(62)	31
Lorraine	Meurthe-et-Moselle (54) Meuse (55) Moselle (57) Vosges (88)	41
Alsace	Bas-Rhin (67) Haut-Rhin (68)	42
France-Comté	Doubs (25) Jura (39) Haute-Saône (70) Territoire de Belfort (90)	43
Pays-de-la-Loire	Loire-Altantique (44) Maine-et-Loire (49) Mayenne (53) Sarthe (72) Vendée (85)	52

Table B.2: Breadown of French regions in départements and their SITRAM code (2/4)

Regions	**Département**	**Regional code in SITRAM database**
Bretagne	Côte-d'Armor (22) Finistère (29) Ille-et-Vilaine (35) Morbihan (56)	53
Poitou-Charentes	Charente (16) Charente-Maritime (17) Deux-Sèvres (79) Vienne (86)	54
Aquitaine	Dordogne (24) Gironde (33) Landes (40) Lot-et-Garonne (47) Pyrénées-Atlantiques (64)	72
Midi-Pyrénées	Ariège (09) Aveyron (12) Haute-Garonne (31) Gers (32) Lot (46) Hautes-Pyrénées (65) Tarn (81) Tarn-et-Garonne (82)	73
Limousin	Corrèze (19) Creuse (23) Haute-Vienne (87)	74
Rhône-Alpes	Ain (01) Ardèche (06) Drôme (26) Isère (38) Loire (42) Rhône (69) Savoir (73) Haute-Savoie (74)	82

Table B.3: Breadown of French regions in départements and their SITRAM code (3/4)

Regions	**Département**	**Regional code in SITRAM database**
Auvergne	Allier (03) Cantal (15) Haute-Loire (43) Puy-de-dôme (63)	83
Languedoc-Roussillon	Aude (11) Gars (30) Hérault (34) Lozère (48) Pyrénées-Orientales (66)	91
Provences-Alpes-Côte-d'Azur (PACA)	Alpes-de-Haute-Provence (04) Hautes-Alpes (05) Alpes-Maritimes (06) Bouches-du-Rhône (13) Var(83) Vaucluse (84)	9C
Corse	Corse-du-Sud (2A) Haute-Corse (2B)	9C

Table B.4: Breadown of French regions in départements and their SITRAM code (4/4)

Figure B.1: The French départements

Appendix C

Countries classification

The classification of the countries is based on the SITRAM nomenclature concernings customs and updated in 2005.
This nomenclature consist in 4 levels:

- Level P1 in 4 divisions: European Union, Europe except EU, Other continents and New 10.
- Level P2 in 21 divisions: 9 divisions for EU 15 + 10 divisions for new EU 10, 5 for the rest of Europe and 6 for the other continents
- Level P2 in 47 divisions: All EU countries (15+10), 10 divisions for the rest of Europe and 20 for the other continents
- Level P2 in 230 divisions: it is the county level

P1	P2	P3	P4	
1= European Union				
	01=Benelux			
		011=Belgium-Luxembourg		
			0200=Belgium-Luxembourg	
			0210=Belgium	introduced in database since 1999
			0220=Luxembourg	introduced in database since 1999
		012=Netherlands		
			0300=Netherlands	
	02=Germany			
		021=Germany		
			0400=FRG	Up to 1989
			1200=D.R.G.	Up to 1989
			1300=Germany	since 1990
	03=Italy			
		031=Italy		
			0500=Italy	San Marino included up to 1993
	04=United Kingdom-Ireland			
		041=United kingdom		
			0610=United Kingdom	
		042=Ireland		
			0620=Ireland	
	05=Denmark			
		051=Denmark		
			0700=Denmark	
	06=Greece			
		061=Greece		
			1510=Greece	
	07=Iberian Peninsula			
		071=Spain		
			1410=Spain	
		072=Portugal		
			072=Portugal	
	08=Austria			
		081=Austria		
			0820=Austria	
	09=Sweden and Finland			
		091=Sweden		
			0920=Sweden	
		092=Finland		
			0930=Finland	

Figure C.1: the EU countries breakdown

P1	P2	P3	P4	
2=Europe except EU				
	21=Switzerland and Liechtenstein			
		210=Switzerland and Liechtenstein		
			0810=Switzerland	Liechtenstein included up to 1994
			0830=Switzerland	since 1995
			0840=Liechtenstein	since 1995
	22=Northern Europe			
		221=Northern Europe		
			0910=Norway	Svalbard included up to 1994
			0940=Svalbard (archipelago)	since 1995
		222=Other Europe		
			0703= Faeore Islands	
			0704=Iceland	
	23=Countries of Old USSR			
		231=Old USSR		up to 1991
			1001=USSR	
		232=Soviet Union		
			1005=Soviet Union	in 1992
		233=Baltic States		
			1002=Estonia	since 1992 up to 30 april 2004
			1003=Latvia	since 1992 up to 30 april 2004
			1004=Lithuania	since 1992 up to 30 april 2004
		234=Old URSS - Eastern Europe		
			1006=Ukraine	since 1993
			1007=Byelorussia	since 1993
			1008=Moldavia	since 1993
			1009=Russia	since 1993
		235=Old URSS - Caucasus and Asia		
			1010=Georgia	since 1993
			1011=Armenia	since 1993
			1012=Azerbaidjan	since 1993
			1013=Kazakhstan	since 1993
			1014=Turkmenistan	since 1993
			1015=Uzbekistan	since 1993
			1016=Tadzhikistan	since 1993
			1017=Kirghizia	since 1993
	24=Central and Eastern Europe			
		241=Old Czechoslovakia		
			1310=Czechoslovakia	up to 1993. includes Czech Republic and Slovakia in 1993
			1311=Czech Republic	since 1994 up to 30 april 2004
			1312=Slovakia	since 1994 up to 30 april 2004
		242=Other Central Europe		
			1100=Poland	Up to 30 april 2004
			1320=Hungary	Up to 30 april 2004
		243=Eastern Europe		
			1330=Romania	
			1331=Bulgaria	
	25=Southern Europe			
		251=Old yugoslavia		
			1530= Yugoslavia	up to 1992
			1531=Slovenia	since 1993 up to 30 april 2004
			1532=Croatia	since 1993
			1533=Bosnia-Herzegovina	since 1993
			1534=Yugoslavia-Macedonia	in 1993
			1535=Serbia and Montenegro	since 1994
			1536=Territory ex-Macedonia	since 1994
		252=Rest of Europe		
			1540=Albania	
			0501=Vatican	
			0502=San Marino	since 1994
			1411=Andorra	
			1412=Gibraltar	
			1520=Turkey	
			1550=Malta	up to 30 april 2004

Figure C.2: the Europe except EU countries breakdown

P1	P2	P3	P4	
3=Other Continents (1/4)				
	31=Africa			
		311=Northern Africa		
			1610=Morocco	
			1620=Algeria	
			1630=Tunisia	
			1642=Canary Islands	
			1643=Lybia	
			1644=Egypt	
			1645=Ceuta_and_Melilla	
			1650=Magreb	
		312=Western Africa		
			1701=Mauritania	
			1702=Senegal	
			1703=Mali	
			1704=Gambia	
			1706=Guinea-Bissau	
			1707=Republic of Cape Verde	
			1716=Guinea	
			1717=Sierra Leone	
			1718=Liberia	
			1719=Ivory Coast	
			1721=Burkina Faso	
			1722=Ghana	
			1723=Togo	
			1724=Benin	
			1725=Nigeria	
			1726=Niger	
			1727=Chad	
		313=Southern Central Africa		
			1811=Cameroon	
			1812=Central African Republic	
			1813=Equatorial Guinea	
			1814=Gabon	
			1815=Congo (Brazzaville)	
			1816=Saint Helena and dependencies	
			1822=São Tomé and Príncipe	
			1831=Angola	
			1832=Zambia	
			1833=Namibia	since 1990
			1840=Republic of South Africa	included Namibia up to 1989
			1841=Republic of Botswana	
			1842=Kingdom of Lesotho	
			1843=Kingdom of Swaziland	
		314=Eastern Africa		
			1911=kingdom of Sudan	
			1912=Ethiopia	
			1913=Somalia	
			1915=Eritrea	since 1994 (previously in Ethiopia)
			1914=Djibouti	
			1921=Kenya	
			1922=Uganda	
			1923=Rwanda	
			1924=Burundi	
			1925=Tanzania	
			1926=Malawi	
			1927=Mozambique	
			1928=Zimbabwe	
			1940=Madagascar	
			1941=Comoros	
			1952=Mauritius	
			1953=Seychelles and dependencies	
			1954=British territories of Indian Ocean	

Figure C.3: the Africa countries breakdown

P1	P2	P3	P4	
3=Other Continents (2/4)				
	32=North America			
		321=USA		
			2002=USA and Puerto Rico	
		322=Canada		
			2100=Canada	
			2101=Greenland	
	33=Other America			
		331=Central America		
			2210=Mexico	
			2213=Bermuda	
			2214=Bahamas	
			2215=Belize	
			2221=Guatemala	
			2223=Honduras	
			2224=El Salvador	
			2225=Nicaragua	
			2226=Costa Rica	
			2227=Panama	up to 1980
			2228=Canal area	up to 1980
			2229=Panama (canal included)	since 1981
			2231=Cuba	
			2232=Haiti	
			2233=Dominican Republic	
			2234=Jamaica	
			2236=Barbados	
			2237=Turks and Caicos Islands	
			2238=Cayman Islands	
			2240=Virgin Islands of the USA	
			2241=Trinidad and Tobago	
			2241=Grenada	
			2243=Old West Indies	from 1980 to 1982
			2244=Dominica	since 1980
			2245=Saint-Lucia	
			2246=Saint Vincent and the Grenadines	
			2247=West Indies	from 1983 to 1985
			2248=Antigua and Barbuda	
			2249=Saint Kitts and Nevis	in 1986
			2250=New West Indies	in 1986
			2251=Anguilla	since 1987
			2252=British Virgin Islands-Montserrat	from 1987 to 1994
			2253=British Virgin Islands	since 1995
			2254=Montserrat	since 1995
		332=Atlantic South America		
			2310=Colombia	
			2320=Venezuela	
			2330=Guyana	
			2331=Suriname	
			2332=Old Netherlands Antilles	up to 1986
			2333=Aruba	since 1987
			2334=Netherlands Antilles	
			2340=Brazil	
			2350=Paraguay	
			2360=Uruguay	
			2370=Argentina	
			2371=Falkland Islands and dependencies	
		333=Pacific South America		
			2410=Ecuador	
			2420=Peru	
			2430=Bolivia	
			2440=Chile	

Figure C.4: the America countries breakdown

P1	P2	P3	P4	
3=Other Continents (3/4)				
	34=Asia			
		341=Near East		
			2510=Cyprus	up to 30 april 2004
			2520=Syria	
			2530=Lebanon	
			2540=Israel	
			2570=Gaza and Jericho	since 1995
		342=Middle East		
			2610=Iraq	
			2620=Iran	
			2630=Kuwait	
			2640=Jordan	
			2650= Saudia Arabia	
			2651=Dubai	up to 1987
			2652=Abu Dhabi	up to 1987
			2660=Yemen	since 1991
			2661=North Yemen	up to 1990
			2662=South Yemen	up to 1990
			2663=Bahrain	
			2672=Qatar	
			2674=Arabic states under treaties	up to 1987
			2675=Oman	
			2676=United Arab Emirates	since 1988
		343=Indian Ocean		
			2711=India and Sikkim	
			2712=Pakistan	
			2715=Bangladesh	
			2720=Afghanistan	
			2731=Maldives	
			2740=Sri Lanka	
			2751=Nepal	
			2754=Bhutan	
			2760=Myanmar	Old Burma
		344=Eastern South Asia		
			2810=Thailand	
			2820=Laos	
			2830=Cambodia	old Kampuchea
			2840=Vietnam	
			2851=Malaysia	
			2852=Brunei	
			2853=Singapore	
			2860=Indonesia	
			2870=Portuguese Timor	since 2003
			2875=Macau	
			2880=Philippines	
		345=Japan		
			2900=Japan	
		346=Other Asia		
			3010=China	
			3020=Taiwan	
			3030=Mongolia	
			3041=North Korea	
			3042=South Korea	
			3051=Hong Kong	

Figure C.5: the Asia countries breakdown

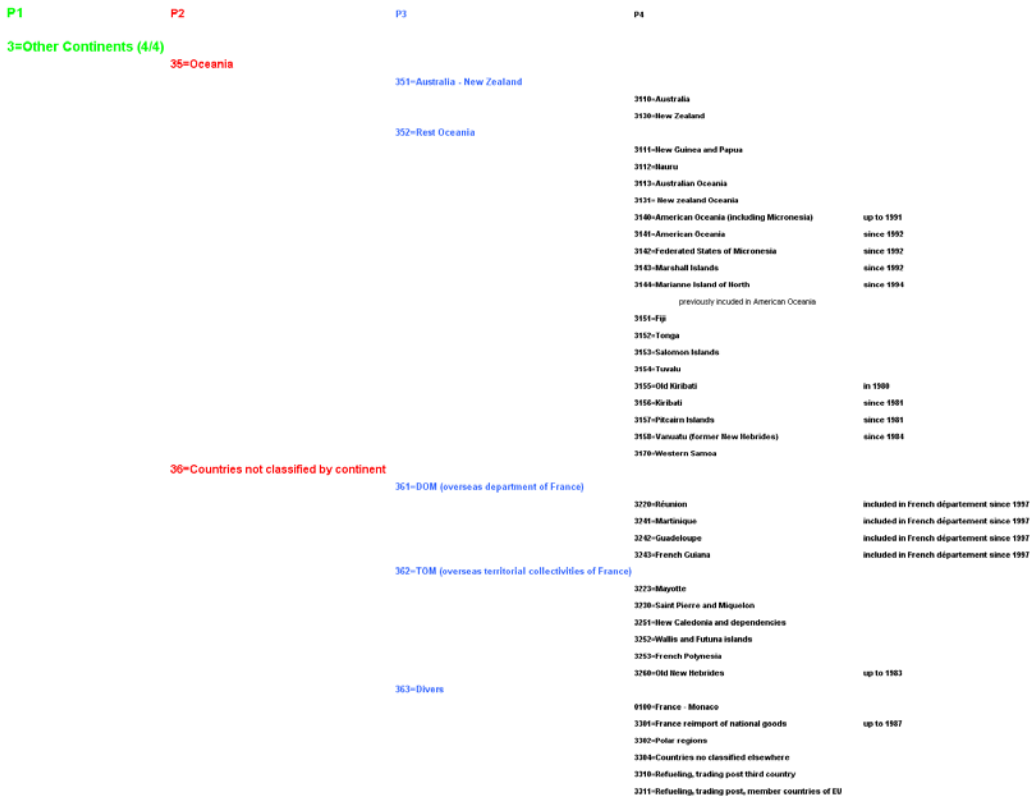

Figure C.6: the Oceania countries breakdown

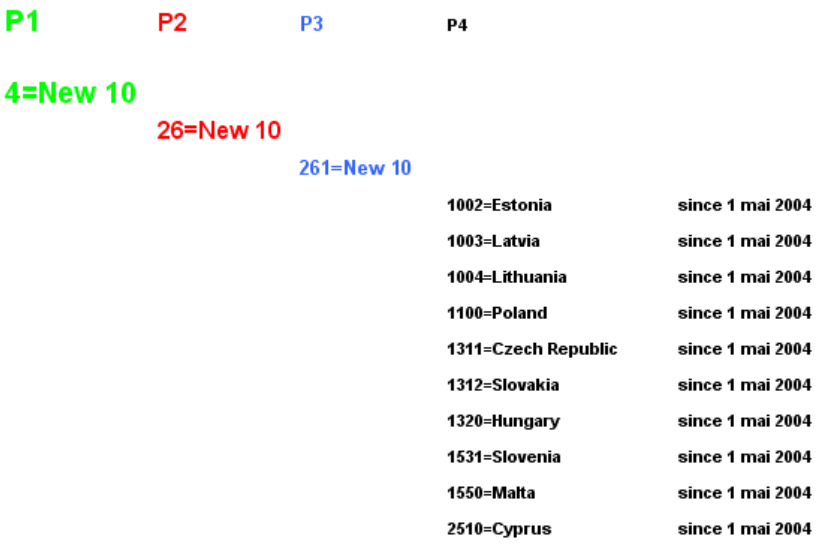

Figure C.7: the new ten countries breakdown

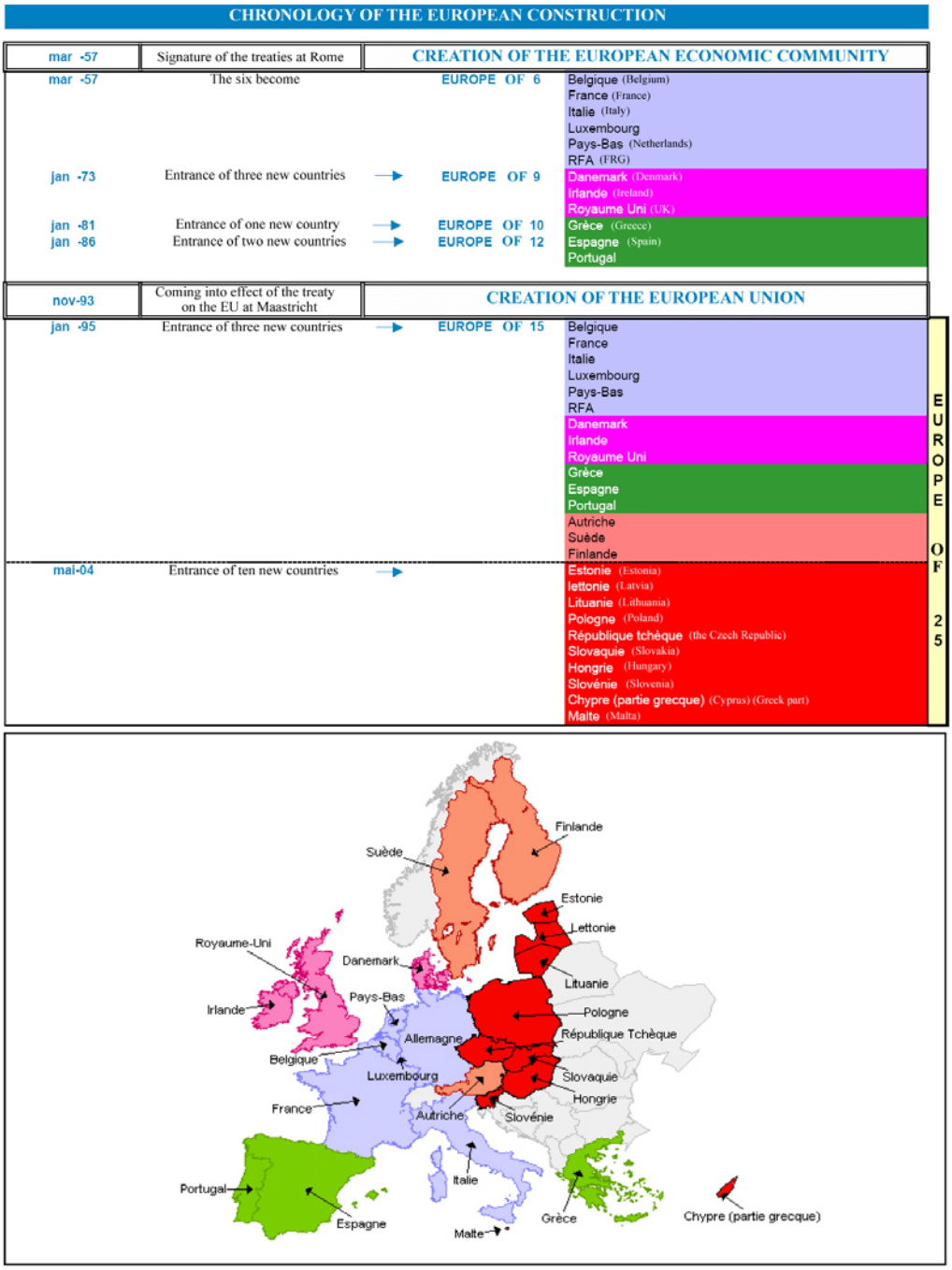

Figure C.8: the construction of the European Union

Appendix D

Emission factor

The emission factors used in the thesis all come from the ADEME software. First, this appendix presents by transport mode the changes made to the initial emission data given by the software. Then, the appendix presents the domestic and the import emission factor used in the thesis.

D.1 Transformation of emission factor

D.1.1 Road emission factor

One of the main difficulties assessing the road emission factors is to take into account the various types of vehicules.

The Ademe software gave emission factors for seven types of vehicles with 17 % of uncertainty concerning the emission factor.

ROAD TRANSPORTATION — *M stands for million*

	% unloaded travel	average tonnage per loaded vehicule	kg CO2-e per vehicule.km	kg CO2 per t-km	uncertainty (emission factor)	lower limit	upper limit	Total Mt-km France other account	% t-km France other account	Contribution to overall emission factor	Total Mt-km France own account	% t-km France own account	Contribution to overall emission factor
TPW 1,5 to 2,5 t (diesel)	20%	0,21	0,224	1,331	17%	1,111	1,550	0	0%	0	0	0%	0
TPW 2,6 to 3,4 t (diesel)	20%	0,36	0,287	0,998	17%	0,833	1,163	0	0%	0	0	0%	0
TPW 3,5 tonnes	20%	0,42	0,330	0,982	17%	0,820	1,144	2,6	0,02%	0,000150	41,4	0,31%	0,00309
TPW 6,1 to 10,9 tonnes	19%	1,65	0,583	0,435	17%	0,363	0,507	281,9	1,66%	0,00720	596,8	3,85%	0,0168
TPW 11 to 19 tonnes	18%	4,24	0,788	0,226	17%	0,189	0,263	11 472,7	67,36%	0,152	6 870,8	45,78%	0,103
TPW 19,1 to 21 tonnes	15%	4,93	0,910	0,217	17%	0,181	0,253	199,3	1,17%	0,00254	185,5	1,41%	0,00306
TPW 21 to 32,6 tonnes	30%	8,27	1,139	0,196	17%	0,164	0,229	5 074,4	29,80%	0,0585	5 396,1	48,64%	0,0956
Road tractors	21%	14,31	0,988	0,0874	17%	0,0730	0,1019	0	0%	0	0,0	0%	0

Table D.1: Breakdown of Road emission factor

Table D.1 shows that the classifaction is based on the Total Permitted weight of the vehicles.
Furthermore, there is initially no distinction between other and own account. In order to take into account all these differentiations, an allocation was made

on the basis of the vehicle park for the two kind of account.

One should note that as the Sitram database does not include light vehicles (TPW >3,5 tons), their emission factor was set to zero. In the same way, as the road tractors were absent from the data on vehicles park, their emission factor was set to zero.

The following tables present the vehicles park and the percentage associated by type of account.

OTHER ACCOUNT

in million tkm

Distance Categories	TPW classes (in tonnes)					
Loaded (in km)	3,6 t to 6,0 t	6,1 t to 10,9 t	11,0 t to 19,0 t	19,1 t to 21,0 t	21,1 t and more	Total
< 25 km	0,0	6,5	169,3	0,3	908,8	1 084,9
From 25 km to 50 km	1,5	16,4	266,0	1,3	524,0	809,3
From 50 km to 100 km	0,2	39,4	739,2	2,6	451,7	1 233,1
From 100 km to 150 km	0,3	55,6	969,8	11,3	368,4	1 405,4
From 150 km to 200 km	0,6	39,9	949,9	15,0	303,9	1 309,3
From 200 km to 300 km	0,0	62,2	1 594,0	40,6	534,6	2 231,3
From 300 km to 400 km	0,0	14,3	1 111,6	40,7	384,2	1 550,8
From 400 km to 500 km	0,0	10,1	1 119,4	20,0	383,4	1 532,8
From 500 km to 1000 km	0,0	37,5	3 750,4	67,6	987,2	4 842,7
1000 km and more	0,0	0,0	803,3	0,0	228,1	1 031,3
All distances	**2,6**	**281,9**	**11 472,7**	**199,3**	**5 074,4**	**17 031,0**

Source : MTETM/SESP, survey TRM 2004

Table D.2: Breakdown of vehicle park per tkm driven for other account

OWN ACCOUNT

Distance Categories	TPW classes (in tonnes)					
Loaded (in km)	3,6 t to 6,0 t	6,1 t to 10,9 t	11,0 t to 19,0 t	19,1 t to 21,0 t	21,1 t and more	Total
< 25 km	0,20%	2,67%	30,25%	0,45%	66,43%	100,00%
From 25 km to 50 km	0,21%	3,44%	32,80%	0,79%	62,76%	100,00%
From 50 km to 100 km	0,29%	4,09%	46,35%	0,88%	48,40%	100,00%
From 100 km to 150 km	0,10%	4,94%	55,48%	1,60%	37,88%	100,00%
From 150 km to 200 km	0,06%	4,70%	55,90%	2,59%	36,75%	100,00%
From 200 km to 300 km	0,97%	5,86%	61,69%	2,62%	28,85%	100,00%
From 300 km to 400 km	0,00%	3,71%	57,56%	2,63%	36,08%	100,00%
From 400 km to 500 km	0,00%	1,67%	51,85%	0,00%	46,48%	100,00%
From 500 km to 1000 km	1,54%	1,15%	63,49%	1,07%	32,75%	100,00%
1000 km and more	0,00%	2,51%	54,64%	15,28%	27,56%	100,00%
All distances	**0,31%**	**3,85%**	**45,78%**	**1,41%**	**48,64%**	**100,00%**

Table D.3: Breakdown of vehicle park per tkm driven for other account (%)

OWN ACCOUNT

in million tkm

Distance Categories	TPW classes (in tonnes)					
Loaded (in km)	3,6 t to 6,0 t	6,1 t to 10,9 t	11,0 t to 19,0 t	19,1 t to 21,0 t	21,1 t and more	Total
< 25 km	5,9	77,5	876,3	12,9	1 924,7	2 897,3
From 25 km to 50 km	4,6	74,3	707,4	17,0	1 353,8	2 157,0
From 50 km to 100 km	6,2	87,8	995,6	18,8	1 039,5	2 147,8
From 100 km to 150 km	1,7	82,0	921,8	26,6	629,3	1 661,5
From 150 km to 200 km	0,7	57,9	688,5	31,9	452,6	1 231,6
From 200 km to 300 km	15,1	91,1	959,6	40,7	448,8	1 555,4
From 300 km to 400 km	0,0	23,5	365,0	16,7	228,8	634,1
From 400 km to 500 km	0,0	4,9	152,4	0,0	136,6	293,9
From 500 km to 1000 km	7,2	5,4	297,6	5,0	153,5	468,7
1000 km and more	0,0	2,6	56,5	15,8	28,5	103,4
All distances	41,4	506,8	6 020,8	185,5	6 396,1	13 150,7

Source : MTETM/SESP, survey TRM 2004

Table D.4: Breakdown of vehicle park per tkm driven for other account

OWN ACCOUNT

Distance Categories	TPW classes (in tonnes)					
Loaded (in km)	3,6 t to 6,0 t	6,1 t to 10,9 t	11,0 t to 19,0 t	19,1 t to 21,0 t	21,1 t and more	Total
< 25 km	0,20%	2,67%	30,25%	0,45%	66,43%	100,00%
From 25 km to 50 km	0,21%	3,44%	32,80%	0,79%	62,76%	100,00%
From 50 km to 100 km	0,29%	4,09%	46,35%	0,88%	48,40%	100,00%
From 100 km to 150 km	0,10%	4,94%	55,48%	1,60%	37,88%	100,00%
From 150 km to 200 km	0,06%	4,70%	55,90%	2,59%	36,75%	100,00%
From 200 km to 300 km	0,97%	5,86%	61,69%	2,62%	28,85%	100,00%
From 300 km to 400 km	0,00%	3,71%	57,56%	2,63%	36,08%	100,00%
From 400 km to 500 km	0,00%	1,67%	51,85%	0,00%	46,48%	100,00%
From 500 km to 1000 km	1,54%	1,15%	63,49%	1,07%	32,75%	100,00%
1000 km and more	0,00%	2,51%	54,64%	15,28%	27,56%	100,00%
All distances	0,31%	3,85%	45,78%	1,41%	48,64%	100,00%

Table D.5: Breakdown of vehicle park per tkm driven for other account (%)

Tables D.2 to D.5presents the tkm by vehicles weight along with the distance driven.
As a allocation by distances was not feasible, the allocation by TPW for all distances was the one used and is reported in table in tableD.1.

Finally, combining the results issued from the previous table and summarized in table D.1, the road emission factors stands as follows:

		lower limit	upper limit
Overall kgCO2 per t-km (other account)	0,221	0,183	0,258
Overall kg CO2 per t-km (own account)	0,222	0,184	0,260

Table D.6: The road emission factors

D.1.2 Railway emission factor

RAILWAY TRANSPORTATION	kg CO2-e per t-km	uncertainty (emission factor)	lower limit	upper limit
Train in France, average	0,0075	10%	0,0068	0,0083
Train in France, electric traction	0,0019	10%	0,0017	0,0021
Train in France, diesel traction	0,055	10%	0,050	0,061
Train in Germany	0,032	20%	0,026	0,038
Train in Austria	0,013	20%	0,010	0,015
Train in Belgium	0,019	20%	0,015	0,022
Train in Denmark	0,038	20%	0,030	0,045
Train in Spain	0,035	20%	0,028	0,041
Train in Finland	0,020	20%	0,016	0,024
Train in Greece	0,044	20%	0,036	0,053
Train in Ireland	0,058	20%	0,047	0,070
Train in Italy	0,029	20%	0,023	0,035
Train in Luxembourg	0,025	20%	0,020	0,030
Train in Norway	0,0082	20%	0,0066	0,0099
Train in Netherlands	0,030	20%	0,024	0,036
Train in Portugal	0,044	20%	0,036	0,053
Train in UK	0,041	20%	0,033	0,049
Train in Sweden	0,0043	20%	0,0034	0,0051
Train in Switzerland	0,0036	20%	0,0029	0,0044
Train in Europe (Average EU-17)	0,023	20%	0,018	0,027

Table D.7: The rail emission factors

Table D.7 presents the emission factors of train for the european countries.
For France, three emission factors are given, making the difference between electric and diesel traction.

For the purpose of this thesis, the type of train used for the transportation of each good being unknwown, the average emission factor has been taken into account.

Concerning countries outside the range of data provided here, typically non European countries, it was assumed the average EU-17 factor emission. This hypothesis is quite high since the emission factor can vary significantly according to the energy source: from high for coal-based electricity to low for nuclear and hydropower based electricity (case of France).

D.1.3 Waterway emission factor

	kg CO2-e per t-km	uncertainty (emission factor)	lower limit	upper limit
Average boat	**0,038**	**20%**	**0,03012927**	**0,04519391**

Table D.8: The waterway emission factor

Only one emission factor was given in the ADEME database for waterway transportation.
As a result, it was assumed that the waterway emission factor was the same for import and domestic transportation and the same for own and other account.

D.1.4 Maritime emission factor

MARITIME TRANSPORTATION

	Tons of Heavy fuel per day	Tons of gazoline per day	Deadweight tonnage (DWT)	Loading rate (% of DWP)	Speed (knot)	kg CO2-e per t-km	uncertainty (emission factor)	lower limit	upper limit
cargo multi-purpose (roll-on roll-off ferry included)	27	2,0	20 000	60%	17	0,010	20%	0,008	0,012
cargo multi-purpose (roll-on roll-off ferry included)	18	2,0	20 000	60%	15	0,008	20%	0,006	0,009

	Tons of Heavy fuel per day	Tons of gazoline per day	max carried tonnage	Loading rate (% of max. tonnage)	Speed (knot)	kg CO2-e per t-km	uncertainty (emission factor)	lower limit	upper limit
Bulk carrier handysize 1970	30,0	1,5	20 000	80%	13	0,011	20%	0,009	0,013
Bulk carrier handysize 1980	29,0	1,5	20 000	80%	13	0,010	20%	0,008	0,012
Bulk carrier handysize 1990	21,0	1,5	20 000	80%	13	0,0076	20%	0,0061	0,0091
Bulk carrier handymax 1980	30,0	1,5	40 000	80%	14	0,0049	20%	0,0040	0,0059
Bulk carrier handymax 1990	22,5	1,5	40 000	80%	14	0,0038	20%	0,0030	0,0045
Bulk carrier Panamax 1970	50,0	2,0	70 000	80%	14	0,0047	20%	0,0037	0,0056
Bulk carrier Panamax 1980	36,0	2,0	70 000	80%	15	0,0032	20%	0,0025	0,0038
Bulk carrier Panamax 1990	32,0	2,0	70 000	80%	15	0,0028	20%	0,0023	0,0034
Bulk carrier Capesize 1970	65,0	2,0	150 000	80%	15	0,0026	20%	0,0021	0,0031
Bulk carrier Capesize 1980	50,0	2,0	150 000	80%	15	0,0020	20%	0,0016	0,0024
Bulk carrier Capesize 1990	47,5	2,0	150 000	80%	15	0,0019	20%	0,0015	0,0023

Table D.9: The maritime emission factors

Two set of data exist for the maritime transportation. One is concerning the cargo multi-purpose and the other is concerning bulk carriers as shown in table D.9.

The non-availability of data about the park of bulk carriers and cargo and the repartition of the tkm along the categories presented in table D.9 being unknown, the following average value was assumed for all type of maritime transportation:

$$F_{CO_2} = \frac{1{,}0+0{,}8+1{,}1+1{,}0+0{,}76+0{,}49+0{,}38+0{,}47+0{,}32+0{,}28+0{,}26+0{,}20+0{,}19}{1300} = 0,0056$$

D.1.5 Air emission factor

AIR TRANSPORTATION	kg CO2-e per t-km	uncertainty (emission factor)	lower limit	upper limit
Short-distance aircraft (< 1000 km)	1,028	20%	0,822	1,233
Middle-distance aircraft (1000 à 4000 km)	0,997	20%	0,797	1,196
Long-distance aircraft (> 4000 km)	0,481	20%	0,385	0,577
cargo	0,650	20%	0,520	0,780

Table D.10: The air emission factors

The air emission factors concerns four types of transportation as shown in table D.10.

As no information were available on the use of cargo, it was assumed that the air transportation of goods was only made by the aircraft transportation. Then, based on the average distance between the countries and France, one of the three aircraft categories was assigned to the imported goods.

One should note that no air emission factor or maritime transportation is included in the domestic emission factors; Actually, only the terrestrial transportation was taken into account for the evaluation of the impact driven by domestic transportation of goods.
In the same way, only values regarding terrestrial transporation were available for assessing the consistency of the data used in the analysis. (see E)

A special note can also be specified regarding air emission. In the ADEME database, only the six main GHG are taken into account, those regulated by the Kyoto protocol. Consequently, Nitroux oxide NO_x are not taken into account in the emission factors. This seems to be of a relevant importance for air emission as shown by figure D.1.

The following pages presents the emission factors used in the analysis. (see C for explanations about reference countries)

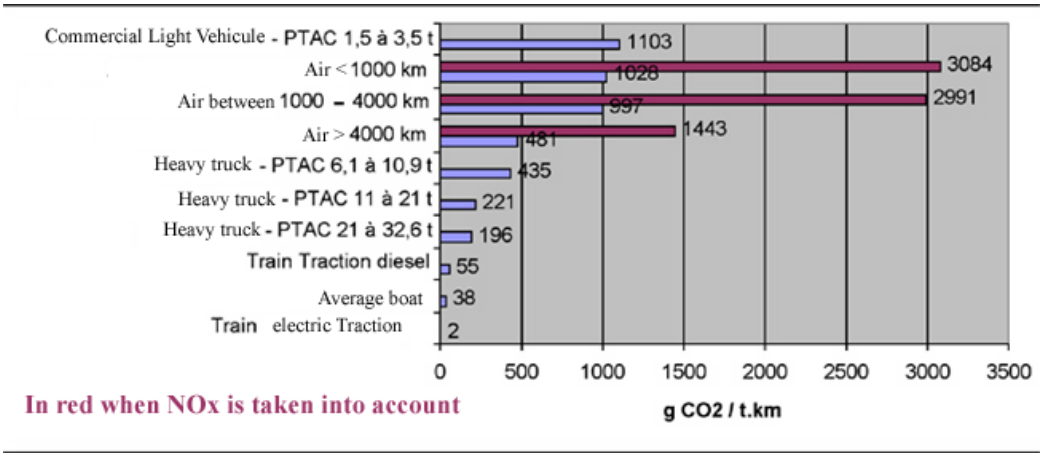

Figure D.1: Emission factors including NO_x emissions

D.2 Emission factors used in the thesis

D.2.1 Domestic emission factors

S_CO2_tkm_dom	kg CO2-e per t-km	lower limit	upper limit
Road (other account)	0,22	0,18	0,26
Road (own account)	0,22	0,18	0,26
water (other account)	0,038	0,030	0,045
water (own account)	0,038	0,030	0,045
Rail	0,0075	0,0068	0,0083

D.2.2 EU countries emission factors

S_CO2_tkm_Belgium	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,019	0,015	0,022
Air transportation	1,028	0,822	1,233
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Netherland	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,030	0,024	0,036
Air transportation	1,028	0,822	1,233
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Germany	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,032	0,026	0,038
Air transportation	1,028	0,822	1,233
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Italy	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,029	0,023	0,035
Air transportation	1,028	0,822	1,233
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_UK	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,041	0,033	0,049
Air transportation	1,028	0,822	1,233
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Ireland	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,058	0,047	0,070
Air transportation	1,028	0,822	1,233
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Danemark	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,038	0,030	0,045
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Greece	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,044	0,036	0,053
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Spain	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,035	0,028	0,041
Air transportation	1,028	0,822	1,233
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Portugal	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,044	0,036	0,053
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Austria	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,013	0,010	0,015
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Sweden	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,004	0,003	0,005
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Finland	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,020	0,016	0,024
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

D.2.3 New ten emission factors

S_CO2_tkm_Lituania	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,1765	0,2647
Railway transportation	0,023	0,018	0,027
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

D.2.4 Europe except EU countries emission factors

S_CO2_tkm_Switzerland	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,004	0,003	0,004
Air transportation	1,028	0,822	1,233
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Norway	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,008	0,007	0,010
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Iceland	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Russia	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Azerbaïdjan	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Roumania	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Croatia	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Turkey	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

D.2.5 Africa emission factors

S_CO2_tkm_Algeria	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_IvoryCoast	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Angola	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Madagascar	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

D.2.6 America emission factors

S_CO2_tkm_US	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Canada	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Mexico	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Argentina	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Peru	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

D.2.7 Asia emission factors

S_CO2_tkm_Liban	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,997	0,797	1,196
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_SaudiaArabia	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_India	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Thaïlande	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Japon	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_China	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

D.2.8 Oceania emission factors

S_CO2_tkm_Australia	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Fidji	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_FrenchGuyana	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_NouvelleCalédonie	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,023	0,018	0,027
Air transportation	0,481	0,385	0,577
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

S_CO2_tkm_Monaco	kg CO2-e per t-km	lower limit	upper limit
Sea transportation	0,0056	0,0044	0,0067
Railway transportation	0,008	0,006	0,009
Air transportation	1,028	0,822	1,233
Road transportation	0,22	0,18	0,26
Waterway transportation	0,038	0,030	0,024
Other transportation mode	0	0	0

Appendix E

Uncertainties

The emissions are estimated using the following formula:

$$\mathbf{f_{CO_2} = F_{CO_2} * F_{tkm} * L_{IxI} * y = F_{CO_2} * F_{tkm} * x = F_{CO_2} * f_{tkm}} \quad \text{(E.1)}$$

Consequently, the uncertainties associated are given as follows

$$\frac{\mathbf{\Delta f_{CO_2}}}{\mathbf{f_{CO_2}}} = \frac{\mathbf{\Delta F_{CO_2}}}{\mathbf{F_{CO_2}}} + \frac{\mathbf{\Delta F_{tkm}}}{\mathbf{F_{tkm}}} + \frac{\mathbf{\Delta x}}{\mathbf{x}} \quad \text{(E.2)}$$

So, there are three types of uncertainties. One corresponds to the uncertainty associated with the emission factor, another to the uncertainty associated with the calculation of the tkm driven and the last one to the uncertainty associated with the output run by the model.

E.1 Emission factor

The uncertainty associated with each emission factor is given in detail in the appendix D concerning emission factor.
For the purpose of the calculation conducted here, a basic estimate of the uncertainties, I only take into account the uncertainty associated with road transportation since it is the main mode used in transportation of goods. For this mode ADEME provide a 64 % confidence interval.

As a result, $\frac{\Delta F_{CO_2}}{F_{CO_2}} = \pm 0,17$

The uncertainty associated with emission factors is of the random type, meaning that it is not possible to exactly know the error associated with the emission factor. For some transportation mode, the real emission factor can be larger than the one used in the thesis and lower for other transportation mode. Nevertheless, the error is included in the range ±17%

E.2 tkm factor

As two dataset are taken from the SITRAM database, the uncertainty associated with the tkm depends on them.

- the SITRAM data concerning domestic transportation are already given in tkm so that the comparison with reference data is feasible directly.
- the SITRAM data concerning import are given in tonnes and euros. A first comparison is feasible at that level. Then the tons data are multiplied by the distances between regions and countries in order to obtain the tkm driven.

E.2.1 Uncertainty associated with transportation of domestic goods

Tkm in billion tkm

Domestic		Reference	Model values	percentage
Road own account	Tkm	*30,4*	30,4	100,0%
Road other account	Tkm	*148,9*	148,9	100,0%
Waterway	Tkm	4,2	4,2	100,0%
Rail	Tkm	24,3	26,6	109,2%
Total	Tkm	207,7	210,0	101,1%

Table E.1: Evaluation of consistency of the domestic data

The previous table E.1 shows that the five products missing in the analysis does not count for much since the comparison with the reference value argues in favor of a 100 % match.

Actually the reference values are taken from the following table E.2 in which national transportation is the sum of national values and the cabotage value.
Cabotage refers to the transportation entirely made on the territory of one country (here France) by a vehicle registered in another country.

As such, one can see that in table E.1 are not included the cabotage and the road transportation made by vehicles of which the Total Weight Permitted is inferior to 3,5 tons.

The following table E.3 presents a synopsis of the domestic data used in the thesis.

Terrestrial interior transportation of goods *In billion tkm*

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Railway transportation (1)	**57,7**	**56,1**	**52,7**	**52,7**	**52,9**	**53,7**	**52,2**	**52,4**	**51,2**	**45,6**	**48,9**	**48,3**	**50,1**	**54,2**	**54,1**	**54,5**	**57,7**	**51,7**	**51,3**	**48,1**	**46,3**	**40,7**	**41,2**
National	34,6	34,2	32,9	33,1	32,5	32,3	31,5	31,7	30,3	26,7	27,4	26,3	26,7	28,0	27,5	28,5	29,9	26,5	26,5	25,2	24,3	21,6	22,8
International	17,4	16,3	14,3	14,0	14,8	15,7	15,0	14,9	14,6	12,9	14,2	14,4	14,7	16,0	17,1	16,8	18,5	17,0	17,0	15,8	15,6	13,9	13,2
Transit	5,7	5,6	5,5	5,7	5,6	5,7	5,7	5,9	6,3	6,0	7,3	7,5	8,7	10,2	9,5	9,2	9,3	8,2	7,9	7,1	6,5	5,2	4,9
Road transportation	**125,9**	**128,4**	**134,6**	**144,5**	**161,1**	**168,6**	**193,9**	**199,6**	**205,0**	**201,1**	**213,7**	**227,1**	**231,1**	**238,2**	**246,5**	**260,3**	**266,5**	**273,7**	**277,0**	**278,8**	**301,4**	**299,2**	**310,5**
French Flag (2)	**114,7**	**116,4**	**121,4**	**130,2**	**145,3**	**151,7**	**155,8**	**159,9**	**163,7**	**158,2**	**166,7**	**178,9**	**180,1**	**183,6**	**189,8**	**201,0**	**203,0**	**208,5**	**208,7**	**209,9**	**218,5**	**214,5**	**218,4**
National TPW*>3,5t)	94,0	94,9	98,9	106,0	117,9	123,1	123,2	126,0	128,0	123,4	129,9	141,1	142,1	144,3	149,5	158,9	163,0	168,7	170,0	171,2	179,2	177,4	180,9
Own account (9)													*36,6*	*34,9*	*31,4*	*30,5*	*28,6*	*30,4*	*31,8*	*31,7*	*30,4*	*30,2*	*31,6*
Other account(9)													*105,5*	*109,4*	*118,1*	*128,4*	*134,5*	*138,3*	*138,2*	*139,4*	*148,9*	*147,2*	*149,4*
International (TPW*>3,5t)	9,0	9,2	9,7	10,9	13,4	14,4	16,8	17,0	18,3	17,0	18,6	19,6	19,9	20,8	21,5	22,7	20,7	19,9	18,1	17,7	17,8	15,4	15,4
National (TPW*≤3,5t)	11,7	12,3	12,8	13,3	14,0	14,3	14,5	15,3	15,8	16,1	16,5	16,9	17,0	17,4	18,0	18,5	18,8	19,5	20,1	20,6	21,0	21,3	21,7
Transit							1,3	1,6	1,7	1,7	1,6	1,4	1,1	1,1	0,8	0,9	0,5	0,5	0,5	0,4	0,4	0,3	0,3
Foreign Flag (3)	**11,2**	**12,0**	**13,2**	**14,4**	**15,8**	**16,9**	**38,0**	**39,7**	**41,2**	**42,8**	**47,0**	**48,3**	**50,9**	**54,6**	**56,7**	**59,3**	**63,5**	**65,2**	**68,3**	**68,9**	**82,9**	**84,7**	**92,1**
Transit (4)							20,8	22,5	24,0	25,2	27,6	28,9	30,3	32,4	33,0	34,4	36,5	38,7	40,4	40,7	50,5	50,8	56,2
International (5)	11,2	12,0	13,2	14,4	15,8	16,9	17,2	17,3	17,2	17,6	19,4	19,4	20,6	22,2	23,7	23,3	24,8	23,7	24,5	24,4	27,5	29,1	31,0
Cabotage (6)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,6	2,2	2,8	3,4	3,8	4,8	4,9	5,0
Waterway transportation (7)	**8,0**	**7,6**	**7,0**	**6,7**	**6,6**	**6,8**	**7,2**	**6,8**	**6,9**	**6,0**	**5,6**	**5,9**	**5,7**	**5,7**	**6,2**	**6,8**	**7,3**	**6,7**	**6,9**	**6,9**	**7,3**	**7,9**	**8,0**
National	5,0	4,5	4,1	3,9	3,7	3,9	4,3	4,3	4,3	3,5	3,1	3,2	3,2	3,1	3,5	4,1	4,1	3,6	3,9	4,0	4,2	4,6	4,6
International	3,0	3,1	2,9	2,8	3,0	2,8	2,9	2,5	2,7	2,5	2,4	2,7	2,5	2,5	2,8	2,7	3,1	3,1	3,0	2,9	3,2	3,2	3,3
Oil pipelines (8)	**25,9**	**24,1**	**27,0**	**25,3**	**29,3**	**23,0**	**19,6**	**22,5**	**23,4**	**23,3**	**22,2**	**22,3**	**21,9**	**22,1**	**21,6**	**21,3**	**21,7**	**22,1**	**21,0**	**22,1**	**20,6**	**20,9**	**21,8**
Produits finis	5,3	5,1	5,6	5,5	5,3	5,6	5,7	5,9	5,6	5,4	5,4	6,1	6,6	6,5	6,7	6,7	6,7	7,1	7,0	6,8	6,8	6,9	-
Produits bruts	20,6	19,1	21,4	19,8	23,9	17,4	13,9	16,6	17,7	17,9	16,8	16,2	15,3	15,6	14,9	14,6	15,0	15,0	14,0	15,3	13,8	13,9	-
TRANSPORTATTION ALLTOGETHER	**217,4**	**216,2**	**221,3**	**229,2**	**250,0**	**252,1**	**272,9**	**281,4**	**286,4**	**275,9**	**290,3**	**303,6**	**308,9**	**320,3**	**328,4**	**343,0**	**353,1**	**354,3**	**356,2**	**355,9**	**375,6**	**368,7**	**381,4**
NATIONAL	145,3	145,9	148,7	156,2	168,1	173,6	173,5	177,3	178,3	169,7	177,0	187,4	189,1	192,9	198,4	211,6	218,1	221,0	223,8	224,8	233,6	229,9	235,1
INTERNATIONAL	*66,4*	*64,7*	*67,1*	*67,3*	*76,3*	*72,8*	*71,6*	*74,2*	*76,1*	*73,4*	*76,8*	*78,3*	*79,7*	*83,7*	*86,7*	*86,9*	*88,7*	*85,8*	*83,6*	*82,9*	*84,6*	*82,5*	*84,6*
TRANSIT	*5,7*	*5,6*	*5,5*	*5,7*	*5,6*	*5,7*	*27,8*	*29,9*	*32,0*	*32,8*	*36,5*	*37,8*	*40,1*	*43,7*	*43,3*	*44,6*	*46,4*	*47,4*	*48,8*	*48,2*	*57,4*	*56,3*	*61,4*

Sources: SNCF, ERC, Véolia Cargo, VNF, Observatoire de l'Energie, MEDAD/SESP, Eurostat-calculs MEDAD/SESP

**TPW stands for Total Permitted Weight and corresponds to PTAC in French*

(1) Including new railway operateur for the total network, only SNCF for the decomposition. For SNCF, tkm taxed on network, including goods coming from other network; transportation by wagon, including vehicle services and non-including personal empty wagon, road transport and expeditions.

(2) Inland transportation of car with a French registration number, Total Permitted Weight greater than 3,5 tons and being less than 15 years old (at least live load of 3 tons up to 2000) except for the "National" line (TPW<3,5 t), estimated from Trafic assesment. Series several times retropolated , to take into account modfications in TRM survey.

(3) Inland transportation by car with a non-French registration number and with a TWP greater than 3,5 tons.

(4) Evolution 2006 estimate from partial trimestrial results of european TRM surveys. Works conducted in 2007 in the perspective of a rebasement give level superior to 60 billion tkm.

(5) Evolution 2006 estimate from partial trimestrial results of european TRM surveys. Works conducted in 2007 in the perspective of a rebasement give a level of to 46,3 billion tkm.

(6) Estimation 2006 protective: similar evolution to the one of French heavy truck at national level

(7) Except rhenish transit

(8) Temporary 2006 Data

(9) Series retropolatd on the basis of TRM surveys since 1996.

Table E.2: terrestrial transportation

tonnages in Million tons, Tkm in billion tkm, distance in km

Domestic		Model values
Road own account	**Tonnages**	806,5
	Tkm	30,4
	Average distance	37,7
Road other account	**Tonnages**	1200,2
	Tkm	148,9
	Average distance	124,0
Waterway own account	**Tonnages**	4,1
	Tkm	0,4
	Average distance	96,5
Waterway other account	**Tonnages**	23,4
	Tkm	3,8
	Average distance	160,9
Rail	**Tonnages**	74,2
	Tkm	26,6
	Average distance	357,9
Total	**Tonnages**	2108,5
	Tkm	210,0
	Average distance	99,6

Table E.3: The domestic data

E.2.2 Uncertainty associated with transportation of imported goods

Foreign Trade by Transport mode *tonnages in Million tons, value in billion euros*

			1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993 (1)	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Imports CIF																											
Maritime	U.E.(15)	Tonnages	22,4	25,9	30,5	33,8	35,3	31,8	36,2	33,0	27,7	**28,8**	31,7	31,4	31,5	34,8	35,7	36,8	36,7	34,5	35,6	34,9	32,5	32,3	29,9	**31,8**	29,0
		Value	9,0	11,4	13,5	16,4	18,1	13,7	15,2	15,7	17,9	**19,1**	19,5	19,5	17,6	19,1	20,3	21,8	25,2	26,7	28,0	35,1	32,2	31,4	29,4	**31,2**	32,6
	Others	Tonnages	155,1	139,7	119,4	119,1	118,3	122,5	117,1	123,2	135,8	**140,8**	146,1	141,2	137,6	141,1	138,8	137,1	142,6	150,3	135,1	138,9	128,0	124,1	126,8	**130,8**	144,0
		Value	35	38	35	38	38,0	26,8	26,3	27,2	32,6	**33,3**	35,2	28,2	33,2	34,0	35,1	37,0	40,6	39,2	41,6	58,1	58,0	55,4	54,1	**60,4**	73,1
Rail	U.E.(15)	Tonnages	14,4	13,3	12,9	14,2	13,2	11,3	10,4	10,6	10,7	**10,5**	9,6	8,6	6,5	8,0	7,8	7,2	8,1	9,2	9,4	10,5	9,1	8,4	8,0	**8,5**	7,3
		Value	6,3	7,6	7,8	8,1	8,2	7,7	7,9	8,6	9,4	**9,0**	8,2	6,0	4,7	5,5	6,6	6,8	7,5	9,0	9,3	11,1	10,8	10,0	9,8	**8,7**	8,6
	Others	Tonnages	1,7	1,6	1,9	1,6	1,7	1,7	1,8	1,4	1,6	**2,0**	2,2	3,5	0,7	0,6	0,7	0,9	0,9	1,1	0,9	1,1	0,9	1,1	1,2	**0,8**	0,7
		Value	1,21	1,42	1,41	1,42	1,5	1,4	1,3	1,5	1,7	**1,6**	1,6	1,5	0,8	0,8	0,8	1,0	0,9	0,9	0,8	1,0	1,0	1,0	0,8	**0,8**	0,9
Road	U.E.(15)	Tonnages	33,1	34,5	35,9	36,3	38,9	41,6	45,5	50,2	56,0	**60,1**	61,7	61,3	57,9	63,8	64,5	66,1	71,4	75,0	78,3	84,9	79,0	78,6	77,5	**83,2**	80,9
		Value	33	40	45	51	57,4	63,0	68,4	76,0	87,1	**90,6**	90,5	87,0	79,3	90,0	98,9	99,3	105,3	114,8	117,9	133,2	129,8	128,7	128,8	**138,9**	142,9
	Others	Tonnages	3,9	3,8	3,9	4,8	5,8	7,2	9,4	9,3	11,1	**10,4**	8,9	8,9	6,0	9,2	8,2	7,1	7,7	8,8	10,0	10,7	10,4	10,1	11,0	**11,3**	11,8
		Value	7,2	8,7	9,7	11,6	13,1	14,3	16,0	18,4	22,5	**24,6**	25,7	26,7	16,7	19,3	20,4	21,2	25,0	28,5	31,3	37,7	39,1	39,6	41,3	**44,6**	50,4
Water	U.E.(15)	Tonnages	5,8	5,9	5,8	6,3	5,8	5,8	7,8	6,0	6,1	**6,3**	5,7	5,2	3,3	4,2	4,4	4,2	4,1	4,4	4,2	4,4	3,8	3,3	3,3	**3,7**	3,6
		Value	0,84	0,95	1,05	1,27	1,2	1,0	1,0	1,0	1,2	**1,2**	1,0	0,8	0,5	0,6	0,8	0,7	0,7	0,7	0,6	1,0	0,8	3,3	0,7	**0,9**	1,0
	Others	Tonnages	4,3	4,5	4,2	4,0	4,4	4,6	4,2	4,6	6,3	**5,5**	6,1	6,5	0,9	0,8	0,5	0,4	0,4	0,6	0,6	0,8	1,4	1,7	1,7	**2,9**	2,4
		Value	0,80	0,88	1,00	1,07	1,0	0,8	0,7	0,8	1,0	**0,9**	0,8	0,8	0,2	0,1	0,1	0,1	0,1	0,1	0,1	0,2	0,2	0,2	0,1	**0,3**	0,3
Air	U.E.(15)	Tonnages	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,1	0,0	**0,0**	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,1	0,1	0,1	0,1	0,0	**0,0**	0,0
		Value	1,9	2,0	2,3	2,7	2,4	2,2	2,7	4,3	4,6	**3,5**	2,9	3,8	3,0	4,1	3,6	4,0	4,9	5,4	5,2	7,0	6,7	6,6	6,9	**6,2**	7,3
	Others	Tonnages	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,3	**0,2**	0,2	0,2	0,2	0,2	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	**0,4**	0,4
		Value	9,4	9,7	11,6	14,3	16,9	15,1	18,3	16,7	16,5	**17,3**	18,6	17,5	19,2	18,6	20,3	21,4	24,5	28,1	31,8	39,7	37,1	35,1	31,0	**32,8**	33,3
Total	U.E.(15)	Tonnages	85,9	88,0	93,1	97,5	99,9	95,4	103,6	103,2	104,2	**109,5**	113,3	111,8	103,6	115,2	117,7	119,5	125,8	128,9	133,6	141,2	130,8	131,0	131,1	**148,5**	156,7
		Value	52	64	71	81	88,8	88,6	95,8	106,9	122,3	**125,6**	124,4	119,5	106,0	120,3	131,7	134,1	145,8	158,6	164,3	192,1	185,4	181,9	180,4	**194,0**	204,3
	Others	Tonnages	170,8	155,7	135,5	136,6	141,6	150,2	145,7	153,6	170,3	**175,7**	181,3	177,2	163,5	171,5	169,2	166,8	174,2	184,3	174,3	176,6	163,1	161,2	162,3	**172,3**	163,1
		Value	54,7	59,9	60,0	68,0	72,4	60,1	63,7	69,5	84,5	**88,4**	97,0	88,8	80,9	84,0	87,8	92,9	107,2	115,5	126,5	162,8	165,3	154,3	146,5	**154,7**	173,1

Source: MEDAD/SESP - SITRAM Database according to DGDDI data

(1) Change in information gathering method in EU and change of mode definition for the other exchange

(2) The mode "others" (pipelines, own propulsion, etc.) non shown above are included in the total

Table E.4: References values for import data

The values given in table E.4 are the references values for the year 2004 and the comparison with the data used for the analysis are shown in table E.5.

Once again, the eight products missing in the analysis of import data does not look significant for the main mode of transportation. Actually, the missing products seems to aggregate in the other transportation mode for which emission factor was settled equal to zero.

Imports CIF			Reference	Model values	Pourcentage
Maritime	U.E.(15)	Tonnages	31,8	31,2	98,3%
		Value	31,2	31,0	99,5%
	Others	Tonnages	130,8	123,6	94,5%
		Value	60,4	58,9	97,6%
Rail	U.E.(15)	Tonnages	8,5	8,5	100,0%
		Value	8,7	8,7	100,0%
	Others	Tonnages	0,8	0,8	100,0%
		Value	0,8	0,8	100,0%
Road	U.E.(15)	Tonnages	83,2	83,1	99,9%
		Value	138,9	138,9	100,0%
	Others	Tonnages	11,3	11,3	100,0%
		Value	44,6	44,6	100,0%
Water	U.E.(15)	Tonnages	3,7	3,7	100,0%
		Value	0,9	0,9	100,0%
	Others	Tonnages	2,9	2,9	100,0%
		Value	0,3	0,3	100,0%
Air	U.E.(15)	Tonnages	0,0	0,0	93,5%
		Value	6,2	6,2	100,0%
	Others	Tonnages	0,4	0,4	101,1%
		Value	32,8	32,8	100,0%
Total	U.E.(15)	Tonnages	148,5	135,0	90,9%
		Value	194,0	191,9	98,9%
	Others	Tonnages	172,3	141,4	82,0%
		Value	154,7	149,3	96,5%

Table E.5: Evaluation of consistency of the import data

The following tables E.6 and E.7 present respectively a synopsis of the import data and the distance between countries and regions used in the thesis.

tonnages in Million tons, Tkm in billion tkm, distance in km

Imports CIF			Model values
Maritime	U.E.(15)	Tonnages	31
		Tkm	20
		Average distance	651
	Others	Tonnages	124
		Tkm	523
		Average distance	4227
Rail	U.E.(15)	Tonnages	8,5
		Tkm	4,8
		Average distance	566
	Others	Tonnages	0,8
		Tkm	1,9
		Average distance	2281
Road	U.E.(15)	Tonnages	83
		Tkm	54
		Average distance	647
	Others	Tonnages	11
		Tkm	36
		Average distance	3138
Water	U.E.(15)	Tonnages	3,7
		Tkm	1,8
		Average distance	492
	Others	Tonnages	2,9
		Tkm	21
		Average distance	7271
Air	U.E.(15)	Tonnages	0,04
		Tkm	0,04
		Average distance	969
	Others	Tonnages	0,4
		Tkm	2,6
		Average distance	7062
Other	U.E.(15)	Tonnages	8,4
		Tkm	5,1
		Average distance	611
	Others	Tonnages	2,3
		Tkm	4,8
		Average distance	2080
Total	U.E.(15)	Tonnages	135
		Tkm	86
		Average distance	636
	Others	Tonnages	141
		Tkm	589
		Average distance	4162

Table E.6: The Import data

DISTANCE IN KM — Prefecture of Regions

Country Description	Capital	11 Ile de France Paris	21 Champagne Ardenne Châlons-en-Champagne /Reims	22 Picardie Amiens	23 Haute Normandie Rouen	24 Centre Orléans	25 Basse Normandie Caen	26 Bourgogne Dijon	31 Nord Pas de Calais Lille	41 Lorraine Metz	42 Alsace Strasbourg
011=Belgium Luxembourg	Brussels (Belgium)	277	152	175	271	388	365	379	91	208	330
012=Netherlands	Amsterdam	444	334	296	403	553	476	559	226	366	475
021=Germany	Berlin	887	733	822	916	989	1 012	817	738	618	604
031=Italy	Rome	1 096	1 062	1 220	1 216	1 086	1 287	846	1 205	961	844
041=United kingdom	London	364	384	214	248	429	242	599	256	515	639
042=Ireland	Dublin	794	839	668	674	827	616	1 043	710	970	1 094
051=Denmark	Copenhagen	1 036	892	919	1 025	1 147	1 105	1 045	839	823	855
061=Greece	Athens	2 094	2 022	2 194	2 208	2 106	2 292	1 842	2 150	1 890	1 766
071=Spain	Madrid	1 009	1 146	1 158	1 054	898	1 011	1 018	1 224	1 224	1 233
072=Portugal	Lisbon	1 433	1 583	1 552	1 445	1 324	1 376	1 499	1 629	1 686	1 716
081=Austria	Vienna	1 042	912	1 064	1 123	1 110	1 223	850	994	761	663
091=Sweden	Stockholm	1 554	1 414	1 424	1 531	1 666	1 604	1 571	1 348	1 349	1 378
092=Finland	Helsinki	1 932	1 786	1 812	1 919	2 042	1 996	1 921	1 733	1 705	1 716
210=Switzerland and Liechtenstein	Berne (Switzerland)	433	380	547	548	457	631	183	524	292	197
221=Northern Europe	Oslo (Norway)	1 415	1 295	1 260	1 364	1 524	1 419	1 491	1 196	1 270	1 330
222=Other Europe	Reykjavik (Iceland)	2 246	2 245	2 090	2 129	2 299	2 090	2 476	2 100	2 341	2 460
234=Old URSS - Eastern Europe	Moscow (Russia)	2 498	2 344	2 427	2 524	2 598	2 618	2 400	2 400	2 222	2 183
235=Old URSS - Caucasus and Asia	Baku (Azerbaidjan)	2 746	2 598	2 716	2 800	2 831	2 900	2 590	2 634	2 457	2 395
243=Eastern Europe	Bucharest (Romania)	1 876	1 757	1 916	1 967	1 929	2 065	1 656	1 849	1 607	1 496
251=Old yugoslavia	Zagreb (Croatia)	1 096	994	1 162	1 198	1 139	1 292	864	1 107	850	731
252=Rest of Europe	Ankara (Turquie)	2 567	2 456	2 618	2 664	2 611	2 760	2 336	2 555	2 307	2 194
261=New 10	Vilnius (Lithuania)	1 704	1 572	1 649	1 749	1 787	1 857	1 632	1 562	1 449	1 387
311=Northern Africa	Algiers (Algeria)	1 336	1 418	1 510	1 431	1 247	1 435	1 202	1 545	1 422	1 366
312=Western Africa	Abidjan (Ivory Coast)	4 841	4 943	5 010	4 917	4 739	4 894	4 739	5 058	4 961	4 908
313=Southern Central Africa	Luanda (Angola)	6 417	6 471	6 589	6 521	6 338	6 534	6 236	6 610	6 432	6 340
314=Eastern Africa	Antananarivo (Madagascar)	8 670	8 642	8 808	8 790	8 642	8 851	8 423	8 784	8 533	8 411
321=USA	Washington DC	6 195	6 285	6 117	6 086	6 715	5 997	6 443	6 174	6 429	6 549
322=Canada	Ottawa	6 163	6 238	6 067	6 049	6 156	5 965	6 415	6 117	6 376	6 498
331=Central America	Mexico (Mexico)	9 206	9 297	9 128	9 098	9 185	9 008	9 454	9 185	9 441	9 560
332=Atlantic South America	Buenos aires (Argentina)	10 990	11 141	11 096	10 991	10 882	10 910	11 048	11 177	11 244	11 265
333=Pacific South America	Lima (Peru)	10 223	10 371	10 254	10 169	10 141	10 069	10 389	10 337	10 513	10 588
341=Near East	Beirut (Lebanon)	2 940	2 845	3 014	3 046	2 969	3 137	2 696	2 958	2 702	2 582
342=Middle East	Riyadh (Saudi Arabia)	4 672	4 577	4 745	4 778	4 699	4 869	4 427	4 688	4 433	4 314
343=Indian Ocean	New Delhi (India)	6 607	6 466	6 597	6 674	6 681	6 775	6 422	6 517	6 319	6 233
344=Eastern South Asia	Bangkok (Thailand)	9 462	9 316	9 434	9 519	9 544	9 619	9 294	9 352	9 173	9 096
345=Japan	Tokyo	9 774	9 632	9 639	9 746	9 895	9 811	9 771	9 566	9 557	9 563
346=Other Asia	Beijing (China)	8 239	8 087	8 133	8 238	8 346	8 319	8 180	8 052	7 984	7 964
351=Australia - New Zealand	Canberra (Australie)	16 918	16 771	16 882	16 971	17 001	17 070	16 748	16 798	16 629	16 552
352=Rest Oceania	Suva (Fiji)	16 607	16 505	16 437	16 528	16 707	16 549	16 709	16 389	16 487	16 538
361=DOM (overseas department of France)	Cayenne (French Guiana)	7 077	7 229	7 136	7 041	6 983	6 945	7 212	7 220	7 361	7 421
362=TOM (overseas territorial collectivities	Noumea (New Caledonia)	16 755	16 615	16 614	16 720	16 866	16 778	16 753	16 543	16 540	16 542
363=Divers	Monaco	696	678	794	804	636	856	447	843	614	547

Country Description	Capital	43 Franche Comté Besançon	52 Pays de la Loire Nantes	53 Bretagne Rennes	54 Poitou Charentes Poitiers	72 Aquitaine Bordeaux	73 Midi Pyrénées Toulouse	74 Limousin Limoges	82 Rhône Alpes Lyon	83 Auvergne Clermont-Ferrand	91 Languedoc Roussillon Montpellier	93 Provence Alpes Côte d'Azur Marseille	94 Corse Ajaccio	Average distance
011=Belgium Luxembourg	Brussels (Belgium)	387	564	498	556	759	829	606	569	570	800	810	1 048	483
012=Netherlands	Amsterdam	564	702	619	717	925	1 006	779	750	752	983	991	1 219	643
021=Germany	Berlin	790	1 193	1 141	1 149	1 323	1 310	1 158	966	1 057	1 224	1 168	1 245	994
031=Italy	Rome	816	1 244	1 299	1 102	1 081	920	1 001	724	857	741	617	317	980
041=United kingdom	London	626	472	366	549	754	870	649	758	692	926	978	1 270	582
042=Ireland	Dublin	1 073	764	663	891	1 058	1 223	1 006	1 185	1 092	1 312	1 385	1 697	981
051=Denmark	Copenhagen	1 028	1 323	1 247	1 315	1 612	1 555	1 352	1 219	1 280	1 478	1 442	1 562	1 182
061=Greece	Athens	1 806	2 283	2 326	2 145	2 134	1 980	2 048	1 758	1 900	1 793	1 670	1 354	1 989
071=Spain	Madrid	1 046	775	880	732	527	511	685	891	779	666	775	1 000	920
072=Portugal	Lisbon	1 532	1 146	1 233	1 158	983	1 021	1 148	1 398	1 270	1 192	1 305	1 530	1 371
081=Austria	Vienna	811	1 327	1 316	1 231	1 343	1 280	1 190	906	1 046	1 118	1 019	952	1 058
091=Sweden	Stockholm	1 554	1 830	1 747	1 833	2 033	2 081	1 875	1 743	1 806	2 003	1 963	2 061	1 699
092=Finland	Helsinki	1 899	2 217	2 138	2 209	2 404	2 436	2 242	2 082	2 160	2 341	2 298	2 344	2 060
210=Switzerland and Liechtenstein	Berne (Switzerland)	146	660	679	544	642	693	490	212	345	460	402	563	451
221=Northern Europe	Oslo (Norway)	1 484	1 655	1 559	1 686	1 896	1 974	1 749	1 678	1 710	1 929	1 914	2 070	1 585
222=Other Europe	Reykjavik (Iceland)	2 498	2 250	2 160	2 377	2 543	2 710	2 491	2 642	2 566	2 794	2 858	3 153	2 432
234=Old URSS - Eastern Europe	Moscow (Russia)	2 367	2 804	2 750	2 754	2 916	2 893	2 751	2 513	2 631	2 751	2 663	2 599	2 573
235=Old URSS - Caucasus and Asia	Baku (Azerbaidjan)	2 552	3 048	3 017	2 968	3 094	3 031	2 938	2 659	2 797	2 862	2 755	2 606	2 772
243=Eastern Europe	Bucharest (Romania)	1 615	2 140	2 145	2 026	2 094	1 972	1 961	1 656	1 807	1 801	1 679	1 461	1 840
251=Old yugoslavia	Zagreb (Croatia)	823	1 346	1 359	1 227	1 295	1 196	1 161	858	1 007	1 014	898	746	1 062
252=Rest of Europe	Ankara (Turquie)	2 296	2 817	2 831	2 694	2 738	2 611	2 618	2 312	2 463	2 421	2 296	2 027	2 509
261=New 10	Vilnius (Lithuania)	1 580	2 047	2 000	[illegible]	2 144	2 116	1 964	1 755	1 857	1 975	1 919	1 869	1 793
311=Northern Africa	Algiers (Algeria)	1 207	1 242	1 347	1 129	945	789	1 024	1 013	1 004	769	778	731	1 177
312=Western Africa	Abidjan (Ivory Coast)	4 747	4 665	4 774	4 591	4 382	4 273	4 508	4 453	4 526	4 301	4 320	4 217	4 671
313=Southern Central Africa	Luanda (Angola)	6 229	6 342	6 448	6 229	6 045	5 889	6 122	6 048	6 080	5 842	5 809	5 582	6 234
314=Eastern Africa	Antananarivo (Madagascar)	8 396	8 754	8 833	8 611	8 502	8 321	8 496	8 280	8 384	8 186	8 095	7 771	8 508
321=USA	Washington DC	6 481	5 997	5 954	6 137	6 171	6 341	6 238	6 522	6 383	6 515	6 632	6 964	6 333
322=Canada	Ottawa	6 451	5 994	5 939	6 137	6 194	6 370	6 244	6 513	6 381	6 535	6 646	6 900	6 292
331=Central America	Mexico (Mexico)	9 492	9 004	8 964	9 143	9 168	9 334	9 242	9 530	9 388	9 513	9 632	9 961	9 315
332=Atlantic South America	Buenos aires (Argentina)	11 078	10 694	10 768	10 717	10 538	10 543	10 703	10 921	10 811	10 678	10 764	10 846	10 900
333=Pacific South America	Lima (Peru)	10 429	9 923	9 952	10 009	9 901	9 990	10 050	10 343	10 197	10 172	10 291	10 516	10 219
341=Near East	Beirut (Lebanon)	2 657	3 161	3 191	3 029	3 040	2 894	2 940	2 640	2 788	2 705	2 580	2 276	2 854
342=Middle East	Riyadh (Saudi Arabia)	4 388	4 888	4 921	4 753	4 752	4 598	4 661	4 364	4 510	4 412	4 288	3 971	4 578
343=Indian Ocean	New Delhi (India)	6 392	6 899	6 802	6 802	6 894	6 794	6 752	6 452	6 601	6 609	6 488	6 251	6 595
344=Eastern South Asia	Bangkok (Thailand)	9 254	9 762	9 736	9 674	9 779	9 689	9 632	9 337	9 484	9 506	9 387	9 159	9 464
345=Japan	Tokyo	9 748	10 043	9 953	10 052	10 252	10 287	10 092	9 927	10 011	10 184	10 119	10 107	9 896
346=Other Asia	Beijing (China)	8 151	8 536	8 461	8 511	8 691	8 686	8 525	8 308	8 418	8 552	8 466	8 389	8 329
351=Australia - New Zealand	Canberra (Australie)	16 708	17 219	17 190	17 129	17 221	17 112	17 080	16 780	16 929	16 923	16 798	16 528	16 907
352=Rest Oceania	Suva (Fiji)	16 700	16 774	16 666	16 853	17 061	17 174	16 939	16 895	16 923	17 147	17 127	17 216	16 770
361=DOM (overseas department of France)	Cayenne (French Guiana)	7 249	6 770	6 816	6 837	6 705	6 772	6 862	7 141	7 001	6 947	7 061	7 260	7 048
362=TOM (overseas territorial collectivities	Noumea (New Caledonia)	16 728	17 015	16 919	17 033	17 235	17 268	17 075	16 902	16 993	17 155	17 080	17 011	16 870
363=Divers	Monaco	412	807	861	966	650	482	544	310	416	284	171	222	593

Table E.7: Distances between countries and regions

The distances have been taken if possible from only one data source. However, Monaco was absent from the web distance calculator and the distances given for Lithuania were wrong since the calculator gave distances up to 5 000 km. As a result, another web distance calculator has been used for those two countries. The capitals were taken as the reference cities but in the case of Lithuania, Vilnius was not available for the distance with Poitiers and Kaunas was taken for this special distance as the reference city. (in red on the table)
Finally, Mappy was used for the distance between Poitiers and Monaco. (in yellow on the table)

The distances do not correspond to the real one driven by goods but is an average. Consequently, there is an uncertainty associated with them. I assume a 10 % for the uncertainty associated with distance.

As a result,
$\frac{\Delta F_{tkm}}{F_{tkm}} = -0,02$ or $\frac{\Delta F_{tkm}}{F_{tkm}} = -0,18$ if other mode is taken into account.

The uncertainty associated with tkm is of the systematic type since it corresponds to missing data in the database.

E.3 Economic factor x

The economic output x is given by the model and the comparison with the initial output g gives an idea of the uncertainty introduced by the model. The difference is really small since it accounts for $1,1510^{-16}$.
As a result, the economic error introduced by the model is considered equal to zero in section E.4 which combines all uncertainties together.

E.4 Overall uncertainty

Combining all the uncertainties, we find that

$$\frac{\mathbf{\Delta f_{CO_2}}}{\mathbf{f_{CO_2}}} = \pm 0,17 + -0,02 + 0 = \{-0,19; +0,15\}$$

Nevertheless, these uncertainties only concerns the running of the model. For example, they do not take into account the absence in the calculation of the transportation made by vehicles of which TPW is inferior to 3,5 tons.Based on table E.2, this transportation can be estimated to 21 Gtkm with an emission factor varying between 0,998 and 1,331 kg CO_2 per tkm. This corresponds to between 356 and 470 kg CO_2 per capita.

Appendix F

Translation of Nomenclatures

PRODUCTS	PRODUITS	
Agriculture, hunting, trapping and related service activities	AGRICULTURE CHASSE SERVICES ANNEXES	GA01
Forestry, logging and related service activities	PRODUITS SYLVICOLES	GA02
Fishing, fish farming and related service activities	PRODUITS DE LA PECHE ET DE L AQUACULTURE	GA03
Production, processing and preserving of meat and meat products	INDUSTRIE DES VIANDES	GD01
Manufacture of dairy products	INDUSTRIE DU LAIT	GD02
Manufacture of beverages	INDUSTRIE DES BOISSONS	GD03
Manufacture of grain mill products, starches and starch products, prepared animal feeds	TRAVAIL DU GRAIN FABRICATION D ALIMENTS	GD04
Manufacture of other food products	INDUSTRIES ALIMENTAIRES DIVERSES	GD05
Manufacture of tobacco products	INDUSTRIE DU TABAC	GD06
Manufacture of wearing apparel; dressing and dyeing of fur	INDUSTRIE DE L HABILLEMENT ET DES FOURRU	GC11
Manufacture of leather and leather products and footwear	INDUSTRIE DU CUIR ET DE LA CHAUSSURE	GC12
Publishing, printing and reproduction of recorded media	EDITION IMPRIMERIE REPRODUCTION	GC20
Manufacture of pharmaceuticals, medicinal chemicals and botanical products	INDUSTRIE PHARMACEUTIQUE	GC31
Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	FABRICATION DE SAVONS DE PARFUM ET DE P	GC32
Manufacture of furniture	FABRICATION DE MEUBLES	GC41
Manufacture of jewellery and musical instruments	BIJOUTERIE ET FABRICATION D INSTRUMENTS	GC42
Manufacture of sports goods, games, toys and others n.e.c.	FABRICATION D ARTICLES DE SPORTS JEUX E	GC43
Manufacture of domestic appliances	FABRICATION D APPAREILS DOMESTIQUES	GC44
Manufacture of television and radio receivers, sound or video recording or reproducing apparatus and associated goods	FABRICATION D APPAREILS DE RECEPTION EN	GC45
Manufacture of optical instruments, photographic equipment, watches and clocks	FABRICATION DE MATERIEL OPTIQUE ET PHOTO	GC46
Manufacture of motor vehicles, bodies and trailers	CONSTRUCTION AUTOMOBILE	GD01
Manufacture of parts and accessories for motor vehicles	FABRICATION D EQUIPEMENTS AUTOMOBILES	GD02
Building and repairing of ships and boats	CONSTRUCTION NAVALE	GE11
Manufacture of railway and tramway locomotives and rolling stock	CONSTRUCTION DE MATERIEL FERROVIAIRE ROU	GE12
Manufacture of aircraft and spacecraft	CONSTRUCTION AERONAUTIQUE ET SPATIALE	GE13
Manufacture of motorcycles, bicycles and other transport equipment n.e.c.	FABRICATION DE CYCLES MOTOCYCLES MATER	GE14
Manufacture of structural metal products	FABRICATION D ELEMENTS EN METAL POUR LA	GE21
Manufacture of tanks, reservoirs, containers of metal ; manufacture of central heating radiators and boilers and steam generators	CHAUDRONNERIE FABRICATION DE RESERVOIRS	GE22
Manufacture of machinery for the production and use of mechanical power	FABRICATION D EQUIPEMENTS MECANIQUES	GE23
Manufacture of other general purpose machinery	FABRICATION DE MACHINES D USAGE GENERAL	GE24
Manufacture of agricultural and forestry machinery	FABRICATION DE MACHINES AGRICOLES	GE25
Manufacture of machine tools	FABRICATION DE MACHINES OUTILS	GE26
Manufacture of other special purpose machinery	FABRICATION D AUTRES MACHINES A USAGE SP	GE27
Manufacture of weapons and ammunition	FABRICATION D ARMES ET MUNITIONS	GE28
Manufacture of office machinery and computers	FABRICATION DE MACHINES DE BUREAU ET MAT	GE31
Manufacture of electric motors, generators and transformers	FABRICATION DE MOTEURS GENERATRICES ET	GE32
Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy	FABRICATION D APPAREILS D EMISSION ET DE	GE33
Manufacture of medical and surgical equipment and orthopaedic appliances	FABRICATION DE MATERIEL MEDICO CHIRURGIC	GE34
Manufacture of industrial process control equipment, instruments and appliances for measuring, checking, testing, navigating	FABRICATION DE MATERIEL DE MESURE ET DE	GE35
Mining of metal ores	EXTRACTION DE MINERAUX METALLIFERES	GF11
Other mining and quarrying	AUTRES INDUSTRIES EXTRACTIVES	GF12
Manufacture of glass and glass products	FABRICATION DE VERRE ET D ARTICLES EN VE	GF13
Manufacture of ceramic goods, products for construction purposes and other non-metallic mineral products	FABRICATION DE PRODUITS CERAMIQUES ET DE	GF14
Preparation and spinning of textile fibres, weaving and finishing of textiles	FILATURE ET TISSAGE	GF21
Manufacture of textile articles, except apparel	FABRICATION DE PRODUITS TEXTILES	GF22
Manufacture of knitted and crocheted fabrics and articles	FABRICATION D ETOFFES ET D ARTICLES A MA	GF23
Manufacture of wood and wood products	TRAVAIL DU BOIS ET FABRICATION D ARTICLE	GF31
Manufacture of pulp, paper and paperboard	FABRICATION DE PATE A PAPIER DE PAPIER	GF32
Manufacture of articles of paper and paperboard	FABRICATION D ARTICLES EN PAPIER ET EN C	GF33
Manufacture of basic inorganic chemicals	INDUSTRIE CHIMIQUE MINERALE	GF41
Manufacture of basic organic chemicals	INDUSTRIE CHIMIQUE ORGANIQUE	GF42
Manufacture of agro-chemical products, paints and other chemical products	PARACHIMIE	GF43
Manufacture of man-made fibres	FABRICATION DE FIBRES ARTIFICIELLES OU S	GF44
Manufacture of rubber products	INDUSTRIE DU CAOUTCHOUC	GF45
Manufacture of plastic products	TRANSFORMATION DES MATIERES PLASTIQUES	GF46
First processing of iron and steel	SIDERURGIE ET PREMIERE TRANSFORMATION DE	GF51
Manufacture of basic precious and non-ferrous metals	PRODUCTION DE METAUX NON FERREUX	GF52
Casting of metals	FONDERIE	GF53
Industrial services for treatment of metals	SERVICES INDUSTRIELS DU TRAVAIL DES META	GF54
Manufacture of fabricated metal products	FABRICATION DE PRODUITS METALLIQUES	GF55
Recycling	RECUPERATION	GF56
Manufacture of electrical equipments and apparatus n.e.c.	FABRICATION DE MATERIEL ELECTRIQUE	GF61
Manufacture of electronic valves, tubes and other electronic components	FABRICATION DE COMPOSANTS ELECTRONIQUES	GF62
Mining of coal and lignite; extraction of peat	EXTRACTION ET AGGLOMERATION DE LA HOUILL	GG11
Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction	EXTRACTION D HYDROCARBURES SERVICES ANN	GG12
Mining of uranium and thorium ores	EXTRACTION DE MINERAIS D URANIUM	GG13
Manufacture of coke oven products and processing of nuclear fuel	COKEFACTION ET INDUSTRIE NUCLEAIRE	GG14
Manufacture of refined petroleum products	RAFFINAGE DE PETROLE	GG15
Electricity supply	PRODUCTION ET DISTRIBUTION D ELECTRICITE	GG2A
Gas, steam and hot water supply	PRODUCTION ET DISTRIBUTION DE COMBUSTIBL	GG2B
Collection, purification and distribution of water	CAPTAGE TRAITEMENT ET DISTRIBUTION D EA	GG22
Construction and installation of buildings	BATIMENT	GH01
Civil engineering works	TRAVAUX PUBLICS	GH02
Sale, maintenance and repair of motor vehicles and motorcycles, retail sale of automotive fuel	COMMERCE ET REPARATION AUTOMOBILE	GJ10
Wholesale trade and commission trade	COMMERCE DE GROS INTERMEDIAIRES	GJ20
Retail trade, repair of personal and household goods	COMMERCE DE DETAIL ET REPARATIONS	GJ30
Transport via railways	TRANSPORTS FERROVIAIRES	GK01
Other passenger land transport	TRANSPORT ROUTIER DE VOYAGEURS	GK02
Freight transport by road or via pipelines	TRANSPORT ROUTIER (OU PAR CONDUITES) DE	GK03
Water transport	TRANSPORTS PAR EAU	GK04
Air transport	TRANSPORTS AERIENS	GK05
Cargo handling, storage and other supporting transport activities	MANUTENTION ENTREPOSAGE ET GESTION D IN	GK07
Activities of travel agencies and tour operators; tourist assistance activities n.e.c.	AGENCES DE VOYAGE	GK08
Activities of other transport agencies, Space transport	ORGANISATION DU TRANSPORT DE FRET ET TRANSPORT	GK09
Financial intermediation	INTERMEDIATION FINANCIERE	GL01
Insurance and pension funding	ASSURANCES	GL02
Activities auxiliary to financial intermediation, insurance and pension funding	AUXILIAIRES FINANCIERS ET D ASSURANCE	GL03
Real estate activities with own property, and on a fee or contract basis	PROMOTION GESTION IMMOBILIERE	GM01
Letting of own property	LOCATION IMMOBILIERE	GM02
Post and courier activities, Telecommunications	TELECOMMUNICATION, POSTE ET COURRIER	GN10
Computer and related activities	ACTIVITES INFORMATIQUES	GN21
Legal, accounting, book-keeping and auditing activities ; business and management consultancy activities	SERVICES PROFESSIONNELS	GN22
Management activities of holding companies	ADMINISTRATION D ENTREPRISES	GN23
Advertising and market research	PUBLICITE ET ETUDES DE MARCHE	GN24
Architectural and engineering activities ; technical testing and consultancy activities	ARCHITECTURE INGENIERIE CONTROLE	GN25
Renting of machinery and equipment without operator and of personal and household goods	LOCATION SANS OPERATEUR	GN31
Labour recruitment and provision of personnel	SELECTION ET FOURNITURE DE PERSONNEL	GN32
Investigation and security activities, industrial cleaning and miscellaneous business activities n.e.c.	SECURITE NETTOYAGE ET SERVICES DIVERS A	GN33
Sewage and refuse disposal, sanitation and similar activities	ASSAINISSEMENT VOIRIE ET GESTION DES DE	GN34
Market Research and development	RECHERCHE ET DEVELOPPEMENT MARCHANDS	GN4A
Non-Market Research and development	RECHERCHE ET DEVELOPPEMENT NON MARCHANDS	GN4B
Hotels and restaurants	HOTELS ET RESTAURANTS	GP10
Motion picture, video, radio and television activities	ACTIVITES AUDIOVISUELLES	GP21
Other entertainment, cultural and sporting activities (museum, library, amusement park)	AUTRES ACTIVITES RECREATIVES CULTURELLE	GP2A
Other entertainment, cultural and sporting activities (sport, gambling activities, natural reserves)	AUTRES ACTIVITES RECREATIVES CULTURELLE	GP2D
Other service activities	SERVICES PERSONNELS	GP31
Activities of households as employers of domestic staff and producers of goods and services for own use	SERVICES DOMESTIQUES	GP32
Market Education	EDUCATION MARCHANDE	GQ1A
Non-Market Education	EDUCATION NON MARCHANDE	GQ1B
Market Human health	SANTE HUMAINE (PARTIE MARCHANDE)	GQ2A
Non-Market Human health	SANTE NON MARCHANDE	GQ2B
Veterinary activities	ACTIVITES VETERINAIRES	GQ2C
Social work activities	ACTION SOCIALE (PARTIE MARCHANDE)	GQ2D
Social work activities	ACTION SOCIALE NON MARCHANDE	GQ2E
Public administration and defence	ADMINISTRATION PUBLIQUE	GP10
Activities of membership organizations and extra-territorial activities	ACTIVITES ASSOCIATIVES	GP20
Products consumed outside the territory	PRODUITS CONSOMMES HORS DU TERRITOIRE DE	PCHTR
Product correction CIF-FOB	Produit CORRECTION CAFFAB	PCAFAB
Total of products	Total des produits	TOTAL

Appendix G

Results

The results as generated by the model are presented in the attached file "results.xls". The following tables corresponds to the Z and A analysis of the food sectors.

Agriculture, hunting, trapping and related service activities		
Ten "Agriculture, hunting, trapping and related service activities" most consumer sectors	Monetary flow (million euros)	% of the total flow of this product
Production, processing and preserving of meat and meat products	11 714	23,6%
Manufacture of dairy products	6 760	13,6%
Manufacture of other food products	4 005	8,1%
Manufacture of grain mill products, starches and starch products, prepared animal feeds	3 274	6,6%
Wholesale trade and commission trade	2 433	4,9%
Hotels and restaurants	2 080	4,2%
Civil engineering works	961	1,9%
Retail trade, repair of personal and household goods	888	1,8%
Construction and installation of buildings	558	1,1%

Table G.1: Ten most consumer sectors of agriculture products

Manufacture of other food products		
Ten "Manufacture of other food products" most consumer sectors	Monetary flow (million euros)	% of the total flow of this product
Manufacture of other food products	2 976	17,4%
Manufacture of dairy products	1 064	6,2%
Wholesale trade and commission trade	994	5,8%
Manufacture of grain mill products, starches and starch products, prepared animal feeds	722	4,2%
Retail trade, repair of personal and household goods	478	2,8%
Agriculture, hunting, trapping and related service activities	433	2,5%
Manufacture of beverages	421	2,5%
Market Human health	352	2,1%
Non-Market Education	329	1,9%

Table G.2: Ten most consumer sectors of other food products

Production, processing and preserving of meat and meat products		
Ten "Production, processing and preserving of meat and meat products" most consumer sectors	Monetary flow (million euros)	% of the total flow of this product
Hotels and restaurants	1 277	18,8%
Non-Market Education	751	11,1%
Wholesale trade and commission trade	443	6,5%
Retail trade, repair of personal and household goods	240	3,5%
Market Education	221	3,3%
Non-Market Human health	176	2,6%
Market Human health	150	2,2%
Manufacture of leather and leather products and footwear	85	1,2%
Manufacture of other food products	83	1,2%

Table G.3: Ten most consumer sectors of meat products

Manufacture of beverages		
Ten "Manufacture of beverages" most consumer sectors	Monetary flow (million euros)	% of the total flow of this product
Manufacture of beverages	1 775	22,1%
Manufacture of dairy products	291	3,6%
Wholesale trade and commission trade	257	3,2%
Manufacture of other food products	209	2,6%
Retail trade, repair of personal and household goods	179	2,2%
Market Human health	142	1,8%
Investigation and security activities, industrial cleaning and miscellaneous business activities n.e.c.	132	1,6%
Construction and installation of buildings	124	1,5%
Manufacture of pharmaceuticals, medicinal chemicals and botanical products	100	1,3%

Table G.4: Ten most consumer sectors of beverages

Manufacture of dairy products		
Ten "Manufacture of dairy products" most consumer sectors	Monetary flow (million euros)	% of the total flow of this product
Hotels and restaurants	1 169	18,1%
Manufacture of other food products	816	12,7%
Wholesale trade and commission trade	354	5,5%
Retail trade, repair of personal and household goods	240	3,7%
Manufacture of grain mill products, starches and starch products, prepared animal feeds	237	3,7%
Market Education	217	3,4%
Market Human health	214	3,3%
Production, processing and preserving of meat and meat products	205	3,2%
Manufacture of beverages	144	2,2%

Table G.5: Ten most consumer sectors of dairy products

Agriculture, hunting, trapping and related service activities	
Ten sectors with highest direct purchase share of "Agriculture, hunting, trapping and related service activities"	% of direct purchase
Production, processing and preserving of meat and meat products	42,6%
Manufacture of dairy products	33,8%
Manufacture of grain mill products, starches and starch products, prepared animal feeds	25,0%
Agriculture, hunting, trapping and related service activities	16,7%
Manufacture of other food products	9,8%
Preparation and spinning of textile fibres, weaving and finishing of textiles	4,7%
Hotels and restaurants	2,8%
Manufacture of rubber products	2,6%
Civil engineering works	2,4%
Manufacture of beverages	2,0%

Table G.6: Ten sectors with highest direct purchase share dedicated to agriculture products

Manufacture of other food products	
Ten sectors with highest direct purchase share of "Manufacture of other food products"	% of direct purchase
Manufacture of other food products	7,3%
Hotels and restaurants	5,5%
Manufacture of grain mill products, starches and starch products, prepared animal feeds	5,5%
Manufacture of dairy products	5,3%
Manufacture of tobacco products	2,1%
Manufacture of beverages	1,6%
Manufacture of basic organic chemicals	1,4%
Market Education	1,2%
Manufacture of man-made fibres	1,1%
Social work activities	1,0%

Table G.7: Ten sectors with highest direct purchase share dedicated to other food products

Production, processing and preserving of meat and meat products	
Ten sectors with highest direct purchase share of "Production, processing and preserving of meat and meat products"	% of direct purchase
Production, processing and preserving of meat and meat products	7,1%
Manufacture of leather and leather products and footwear	2,4%
Hotels and restaurants	1,7%
Market Education	1,3%
Non-Market Education	0,93%
Manufacture of grain mill products, starches and starch products, prepared animal feeds	0,51%
Manufacture of wearing apparel; dressing and dyeing of fur	0,39%
Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	0,35%
Non-Market Human health	0,34%
Wholesale trade and commission trade	0,30%

Table G.8: Ten sectors with highest direct purchase share dedicated to meat products

Manufacture of beverages	
Ten sectors with highest direct purchase share of "Manufacture of beverages"	% of direct purchase
Manufacture of beverages	6,8%
Hotels and restaurants	3,8%
Manufacture of dairy products	1,5%
Market Education	0,59%
Manufacture of other food products	0,51%
Other entertainment, cultural and sporting activities (museum, library, amusement park)	0,37%
Manufacture of pulp, paper and paperboard	0,35%
Manufacture of grain mill products, starches and starch products, prepared animal feeds	0,35%
Manufacture of industrial process control equipment, instruments and appliances for measuring, checking, testing, navigating	0,31%
Manufacture of office machinery and computers	0,29%

Table G.9: Ten sectors with highest direct purchase share dedicated to beverages

Manufacture of dairy products	
Ten sectors with highest direct purchase share of "Manufacture of dairy products"	% of direct purchase
Manufacture of dairy products	7,7%
Manufacture of other food products	2,0%
Manufacture of grain mill products, starches and starch products, prepared animal feeds	1,8%
Hotels and restaurants	1,6%
Market Education	1,3%
Production, processing and preserving of meat and meat products	0,75%
Manufacture of beverages	0,55%
Social work activities	0,40%
Market Human health	0,35%
Wholesale trade and commission trade	0,24%

Table G.10: Ten sectors with highest direct purchase share dedicated to dairy products

Appendix H

Bridges and Initial IO matrix

The Z matrix, the bridges and the files used for their construction are given in attached files.
Only the bridge used for domestic railway is shown as an example here.

	NST_10_sectors		BRIDGE FOR DOMESTIC DATA (RAILWAY)							
NES_116 sectors	0	1	2	3	4	5	6	7	8	9
GA01	0,54	0,20	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GA02	0,10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GA03	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GB01	0,01	0,07	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00
GB02	0,01	0,04	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GB03	0,02	0,18	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,00
GB04	0,01	0,09	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00
GB05	0,05	0,35	0,00	0,00	0,00	0,00	0,01	0,00	0,03	0,00
GB06	0,00	0,03	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GC11	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03
GC12	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05
GC20	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
GC31	0,01	0,00	0,00	0,01	0,01	0,00	0,00	0,06	0,07	0,00
GC32	0,01	0,00	0,00	0,01	0,01	0,00	0,00	0,06	0,07	0,00
GC41	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,04
GC42	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,02
GC43	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,04
GC44	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
GC45	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GC46	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
GD01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
GD02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
GE11	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
GE12	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GE13	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GE14	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
GE21	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,01
GE22	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,02
GE23	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
GE24	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
GE25	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
GE26	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
GE27	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03
GE28	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GE31	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
GE32	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GE33	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GE34	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
GE35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
GF11	0,00	0,00	0,00	0,00	0,34	0,00	0,00	0,00	0,00	0,00
GF12	0,00	0,00	0,07	0,00	0,00	0,00	0,60	0,32	0,00	0,00
GF13	0,00	0,00	0,00	0,01	0,00	0,00	0,06	0,00	0,00	0,02
GF14	0,00	0,00	0,00	0,02	0,00	0,00	0,24	0,00	0,00	0,06
GF21	0,06	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,03
GF22	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
GF23	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
GF31	0,05	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,05
GF32	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,02
GF33	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,04	0,06
GF41	0,01	0,00	0,01	0,02	0,02	0,00	0,01	0,13	0,13	0,00
GF42	0,01	0,00	0,00	0,01	0,02	0,00	0,00	0,10	0,10	0,00
GF43	0,02	0,00	0,01	0,03	0,04	0,00	0,01	0,25	0,27	0,01
GF44	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,03	0,03	0,00
GF45	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GF46	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00
GF51	0,00	0,00	0,00	0,00	0,10	0,43	0,00	0,00	0,02	0,02
GF52	0,00	0,00	0,00	0,00	0,06	0,27	0,00	0,00	0,01	0,02
GF53	0,00	0,00	0,00	0,00	0,05	0,22	0,00	0,00	0,01	0,01
GF54	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,02
GF55	0,00	0,00	0,00	0,00	0,00	0,02	0,00	0,00	0,01	0,05
GF56	0,01	0,00	0,00	0,01	0,08	0,00	0,01	0,00	0,01	0,02
GF61	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03
GF62	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GG11	0,00	0,00	0,38	0,11	0,00	0,00	0,03	0,02	0,00	0,00
GG12	0,00	0,00	0,00	0,13	0,00	0,00	0,00	0,00	0,00	0,00
GG13	0,00	0,00	0,00	0,00	0,05	0,00	0,00	0,00	0,00	0,00
GG14	0,00	0,00	0,35	0,41	0,02	0,01	0,00	0,01	0,02	0,00
GG15	0,00	0,00	0,17	0,21	0,01	0,01	0,00	0,01	0,01	0,00
GG2A	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GG2B	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GG22	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GH01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GH02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GJ10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GJ20	0,00	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GJ30	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GK01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
GK02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
GK03	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
GK04	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GK05	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GK07	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GK08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GK09	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GL01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GL02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GL03	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GM01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GM02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GN10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GN21	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01
GN22	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GN23	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GN24	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GN25	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GN31	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GN32	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GN33	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GN34	0,01	0,00	0,00	0,01	0,13	0,00	0,01	0,00	0,03	0,03
GN4A	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GN4B	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GP10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GP21	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GP2A	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GP2B	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GP31	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GP32	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GQ1A	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GQ1B	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GQ2A	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GQ2B	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GQ2C	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GQ2D	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GQ2E	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GR10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
GR20	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00