CARBON BALANCE®: FROM THE VINE TO THE BOTTLE

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Introduction

The climate is an important component for « terroirs ». Since 1898, the Swedish scientist Arrhenius had envisaged global warming due to the combustion of fossil fuels with the aim to fight against the recession of the glaciers. If a debate was established in 1975 about the contribution of man, the scientific community of the Intergovernmental Panel on Climate Change (IPCC) has since been able to show a close link between global warming and the greenhouse effect.
In the future, the implication of these climatic modifications will not be without consequences on viticulture. Beyond the reflections and studies on adaptation routes for viticultural and oenological techniques in response to this evolution, the industry must limit its impacts on the greenhouse effect. In the first part, the mechanisms of the greenhouse effect and the issues of climate change will be presented. A second part will focus on the quantification of the greenhouse gas emissions in several French exploitations by the Carbon Balance® method.

1. The greenhouse effect

1.1. The greenhouse effect mechanism

The greenhouse effect is a natural and vital phenomenon, without which the temperature at the surface of the earth would be around -18°C instead of around +15°C.

The sun's radiation crosses the clear atmosphere (figure 1). One part of this radiation is reflected by the atmosphere and the surface of the earth (thus is lost in the space), whereas another part is absorbed by the terrestrial surface and it is heated: the solar energy is converted into heat, sending back an emission of infrared radiation towards the atmosphere. One part of the infrared radiation is absorbed and re-emitted by greenhouse gas molecules; the surface of the earth and the troposphere are therefore reheated; the surface of the earth being once again reheated emits once again infrared radiation.

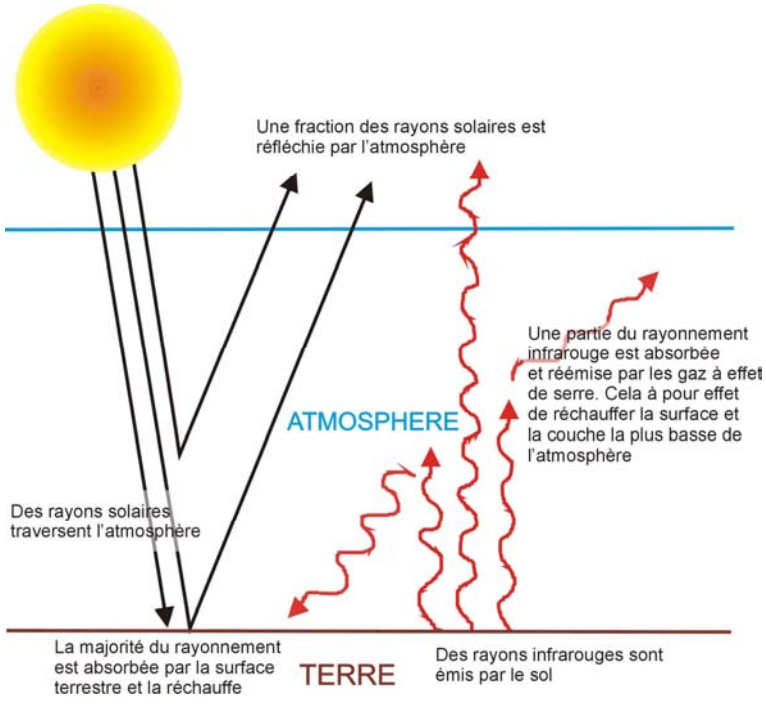


Figure 1 : Greenhouse effect mechanism

1.2 Greenhouse gases

The greenhouse gases (GG) are regrouped in 6 main groups:

- Water vapour (**H_2O**) linked with evaporation;
- **Carbon dioxide** (**CO_2**), coming mainly from the combustion of fossil fuels (coal, gas, fuels derived from petrol), but also from deforestation (burning of cut wood and diminution of the CO_2 removal by plants);
- **Methane** (**CH_4**), coming mainly from the anaerobic degradation of organic matter (fermentation of trash and organic effluents, …), coal mines, cattle raising, rice paddies, …;
- **Nitrous oxide** (**N_2O**), coming mainly from the use of nitrogen fertilizers, but also from the chemical industry
- **Halocarbons and fluorinated hydrocarbons (HFC, PFC, SF_6, but also CFC)**, mainly represented by refrigerant fluids or gases, plastic foams, electronic components, double glazing, aluminum production;
- Without direct emission, but having a consequent impact on the greenhouse effect, **ozone** (**O_3**), whose augmentation in the atmosphere is the consequence of solar radiation on precursors, essentially generated by the use of fossil combustibles. Ozone also has a shielding function against ultraviolet radiation, thus limiting all excessive reheating of the surface of the planet.

These greenhouse gases do not have the same persistence in time, nor the same reheating power. Contributing to 60% of the reheating, CO_2 is considered as the reference gas for the determination of the reheating power **(table 1)**

GG	Persistance (in years)	Reheating Power
CO_2	150	1
CH_4	12	23
CFC	120	16 000
N_2O	120	296
HFC	220	12 000
PFC	50 000	8 700
SF_6	3 200	22 200

Table 1 : Persistance and reheating power of the main greenhouse gases (Source : GIEC 2001)

1.3 Global warming

Taking into account the greenhouse effect, the accumulation of greenhouse gases in the atmosphere has a consequence the augmentation of the average temperature of the surface of the earth. It has since been admitted by the scientific community that the essence of the global warming observed since the middle of the 19th century would be, at a 90% of probability, the direct consequence of greenhouse gas emissions linked with human activities (IPCC – February 2007- see **Box 1**). In effect, a correlation can be established between the evolution of the temperature and the CO_2 concentration in the atmosphere **(figure 2).**

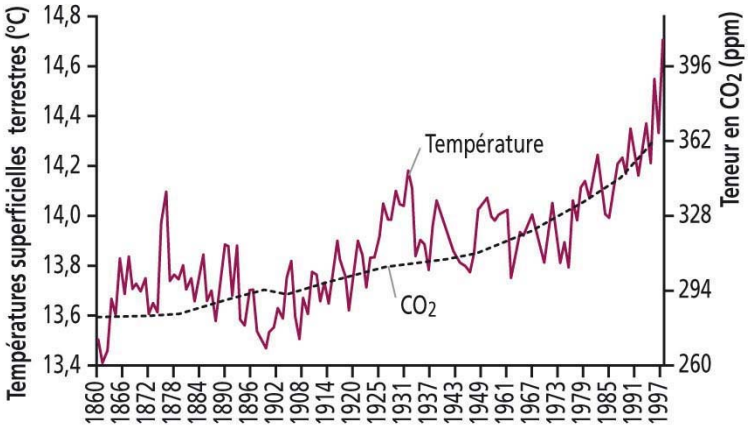


Figure 2 : correlation between the variations in the superficial temperatures and the CO_2 levels since 1860

1.4 Greenhouse gas emissions in France

Greenhouse gas emission in France, in 2004, were estimated at 562,6 millions of tons – CO_2 equivalents (Mt.eq.CO_2) outside of LULUCF (see box 2), and at 510,8 Mt.eq.CO_2 including the LULUCF.

The majority of the reduction of greenhouse gases comes from the industrial sector (-21,6% for the manufacturing industry and -17,0% for the energy industry), followed by agricultural sector (-10,5%) and the waste reprocessing (-8,5%)

The transport sector still constitutes the primary source of greenhouse gas emissions (26% of the total emissions in 2004), and this despite a relative stabilization of road emissions in the last years, this stabilization can be notably attributed to the increase in at the pump prices of fossil fuels. Greenhouse gases emission linked to transport have however increased by 22,7% of the period from 1990-2004. The emissions of automobiles represent 57% of the total road transport emissions; heavy transport vehicles represent 26% and utility vehicles 17%.

The residential habitat and tertiary and commercial sector also conceive a notable increase in greenhouse gas emissions in the period from 1990-2004 (+22,3%).
Concerning the part of emissions from agriculture, 56% is due to N_2O (use of nitrogen fertilizers), 33% due to CH_4 (raising) and 11% due to CO_2 (combustion of fuel for tractors)

In terms of the variation of the greenhouse gas content in the atmosphere in the period from 1990-2004, the CO_2 increased by 5,6% and the HFC by 217% in eq.CO_2; on the other hand, the levels of the other greenhouse gases are decreasing: -14% in eq.CO_2 for CH_4, -24% in eq.CO_2 for N_2O, -46% in eq.CO_2 for PFC and –34% in eq.CO_2 for SF_6

Box 1: Main conclusions of the 4th scientific report of the IPCC

The 2nd February 2007, at the issue of the Conference on climate change which was held in the UNESCO locales in Paris, the 4th scientific report of the Intergovernmental Panel on Climate Change (IPCC) was published. The main conclusions of this report are the following:

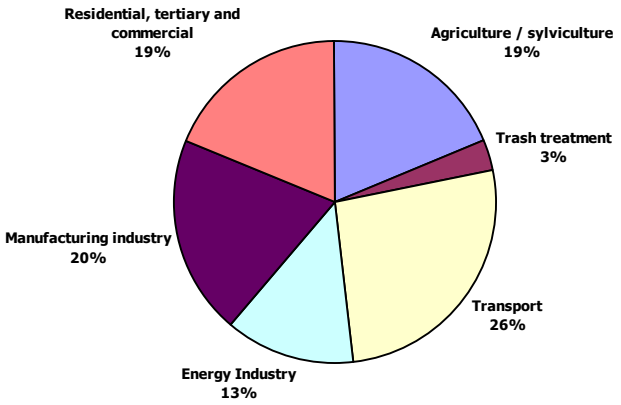
- *It is 90% probable that the greenhouse gases emitted by human activities are responsible for the essence of the global warming observed since the middle of the 20th century;*
- *the probable average increase should be of 3°C from now to the end of the 21st century (increase from 1.8 to 4°C);*
- *The probable elevation level of the oceans should be situated between 19 and 58cm ;*
- *the past and future emissions of greenhouse gases will continue to contribute to global warming, due to their persistence in the atmosphere ;*
- *the future tropical cyclones, typhoons and hurricanes will be presumably more intense (winds and precipitations), in the absence of being more numerous;*
- *it is indispensable to stabilize the CO_2 concentration well below 550ppm, in order to not reach the increase of 2°C, over which the consequences risk to be catastrophic;*
- *case in France : the reduction of greenhouse gas emissions within the 1990-2005 period is of 1,8% with a reduction of 0.5% in 2004.*

Box 2: Definition of LULUCF

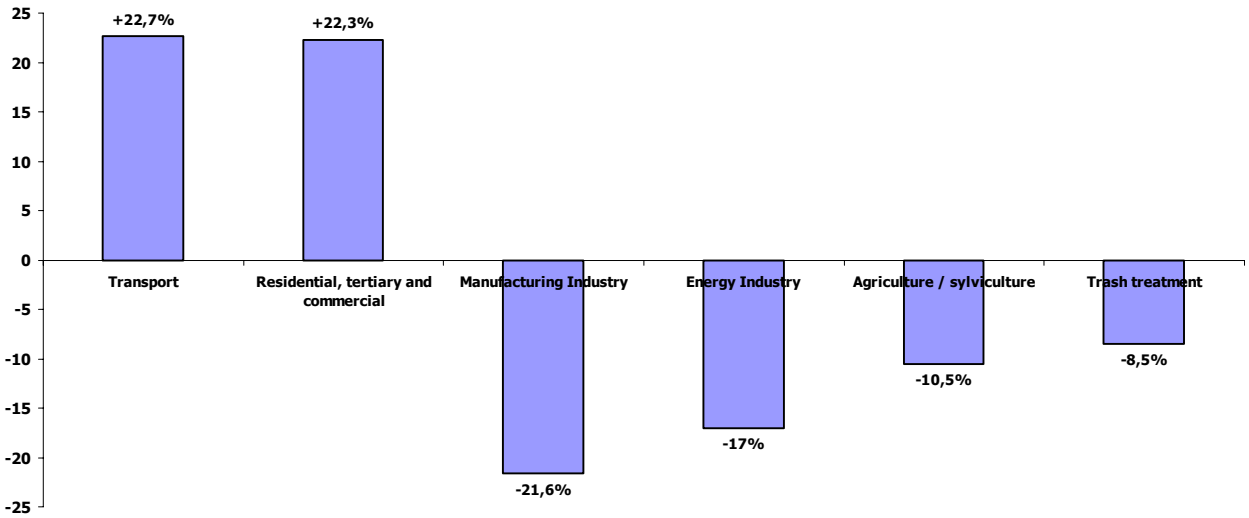
LULUCF : Land use, land use change and forestry

The LULUCF is both a source and sink of emissions of CO_2, CH_4 and N_2O. The LULUCF covers the forestry crops and growth, the conversion of forests (forest clearing) and of prairies as well as the soils of which the carbon composition is sensitive to the nature of the activities to which they are destined for use (forest, prairies, cultivated land)

Graph 1 : Greenhouse gas emissions by sector in France in 2004, outside of LULUCF
(Source : MEDD / CITEPA)



Graph 2 : evolution of greenhouse gas emissions over the period 1990-2004
(source : MEDD / CITEPA)



2. The Carbon Balance®

2.1. Presentation of the Carbon Balance® method

Adjusted by M. JANCOVICI for the ADEME (Agency for environment and energy management) and the MIES (Interministerial Mission of the Greenhouse Effect) in 2003, the Carbon Balance® is a method which allows for the quantification of the contribution of an individual, collective group or enterprise to the greenhouse effect. It takes into account the six families of greenhouse gases present in the Kyoto protocol. Beyond the “diagnostic” aspect, it can also be used as a tool to help in taking decisions concerning investments or for comparing technical itineraries. However, the method cannot, in any situation, be considered as a tool for the grading of exploitations, due to the specific characteristics that each has.

The principal of the completion of a Carbon Balance rests on the collection and input in a spreadsheet of specific numerical data linked to the activities of the exploitation over one year judged as representative of its activity in terms of production and sales. For each data there is a corresponding emission factor which permits for the expression of the results with a common unit: CO_2 equivalents.

There are three possible approaches according to the perimeter that we want to characterize (**figure 3):**

- The **internal** or **juridical** perimeter, which concerns direct emissions, whether they be energy based (linked with energy use, fossil or electric) or not (linked with the use of nitrogen fertilizers, the eventual leakage of refrigerants, the use of exogenous CO_2, …)
- the **intermediary** or **added emissions** perimeter, integrating internal freight and freight towards clients, the displacements of clients to the exploitation, the transport of employees from home to work, the transports linked with the missions of the employees, the fabrication of inputs (including the buying of grapes, must or wine), as well as bought services;
- The **global** or **Carbon Balance®** perimeter, which is the taking into account of an exhaustive ensemble of the emissions attributable to the exploitation, among which are included, the transport of inputs, building construction, waste and used water management and amortization of capital assets.

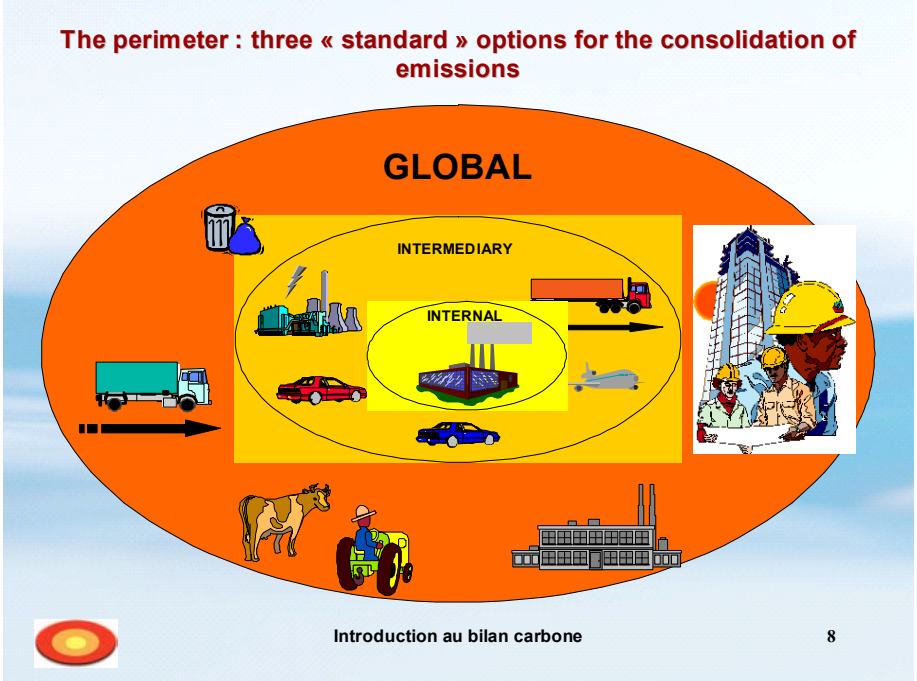


Figure 3 : perimeter approach of the Carbon Balance® method (Source : ADEME)

2.2. Methodology

In 2004, the French Institute of the Vine and of Wine (IFV) integrated the program GESSICA (Gases with Greenhouse Effect: Integrated System for the Accounting in the Agri-Food Industries), piloted by the UNGDA (National Union of the Alcohol Distiller Groupings) and benefit from the financial aid of the ADEME.

This project regroups the institutes of 6 agri-food fields. The IFV, representing the viti-viniculture field, was placed in charge of completing the Carbon Balance® for five viti-viniculture domains **(table 2)**. The five domains transform exclusively grapes from their own exploitation and commercialize the integrality of their production (no buying or selling of grape, musts or wine)

Domaine	Surface in production (ha)	Grape Production (T)	Average Yield (T / ha)	Wine Production (hl)	Average Yield (hl / ha)	Pressing Yield (hl / T)	Shipments (UB)
Domaine 1 (Medoc- Rg)	49,28	402,805	8,2	3098,50	62,9	7,7	320000
Domaine 2 (Medoc - Rg)	114,4551	791	9,9	5858	51,2	7,4	650000
Domaine 3 (Chablis- Bl)	26	195	7,5	1500	57,7	7,7	189404
Domaine 4 (Châteauneuf du Pape - Rg)	150	700	4,7	5500	36,7	7,9	636771
Domaine 5 (Medoc - Rg)	41,76			2542	60,9		262901

Table 2: data relative to the partner viti-viniculture domains

Legend :
Rg : Production of mainly red wines
Bl : production of white wines exclusively
ha : hectare of vines in exploitation over the reference period
T : Tons of grapes collected during the reference harvest
hl : hectoliter of elaborated wine during the reference vinification
UB : Bottle Unit ; the volumes of the different bottlings (half-bottles, bottles, magnums, double-magnums, jeroboams, etc…) sold over the reference period are brought to a unique unit of volume, which is the 0,75 liter bottle.

These data present notable differences from one domain to another ; they are due to numerous parameters :
- meteorological histories differ from one region to another, terroir effect, … ;
- vintage effect;
- vine cultivation practices, yield aimed for the obtaining of an optimal technological maturity, … ;
- juice extraction method (maceration and or pressing, pressing yield, …) ;
- vinification method (red wine/ white wine) ;
- technical itineraries completed by the workers in the vineyards and in the winery

The sum of this variability in fact prohibits the use of the Carbon Balance® method as a tool to complete comparisons between the several domains.

2.3. Results

The contribution to the greenhouse effect is expressed according to specific units: **CO_2 equivalents per hectare, CO_2 equivalents per ton of harvest grapes, CO_2 equivalents per vinified hectoliter** and **CO_2 equivalents per Bottle-Unit produced.**

According to the studies completed by the Interprofessional Comity of Champagne Wine (CIVC), the CO_2 deducted by the vine for photosynthesis is equilibrated by the CO_2 restituted by respiration, the must fermentation, the burning or degradation in the soil after the grinding of pruned wood, as well as the burning of wood frames after removal; the deducted CO_2 and the restituted CO_2 are equilibrated, and are not accountable.

In the method, there is no emission factor for the primary matter « grapes »; in addition, the activities linked with vine cultivation and those linked with the elaboration of wine are often indivisible within a vini-viticultural exploitation.

Thus, two cases were presented:
- For the domains 1 and 2, the data were sufficiently precise to differentiate the viticultural activity from the transformation. Thus, a first Carbon Balance® was completed for the viticultural production, permitting for the obtaining of a specific emission factor for each of the two domains for the “Grape” input.

- For the three other domains (3, 4 et 5), the two activities (viticultural production and transformation) were globalized.
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2.3.1. Viticultural Production

In a general manner, the data relative to this activity are known; on the other hand, the sources linked with administrative tasks and the emissions linked to the promotion of the domains (displacements in France and overseas, representation) are equally distributed across the two activities “viticultural production” and “Transformation”.

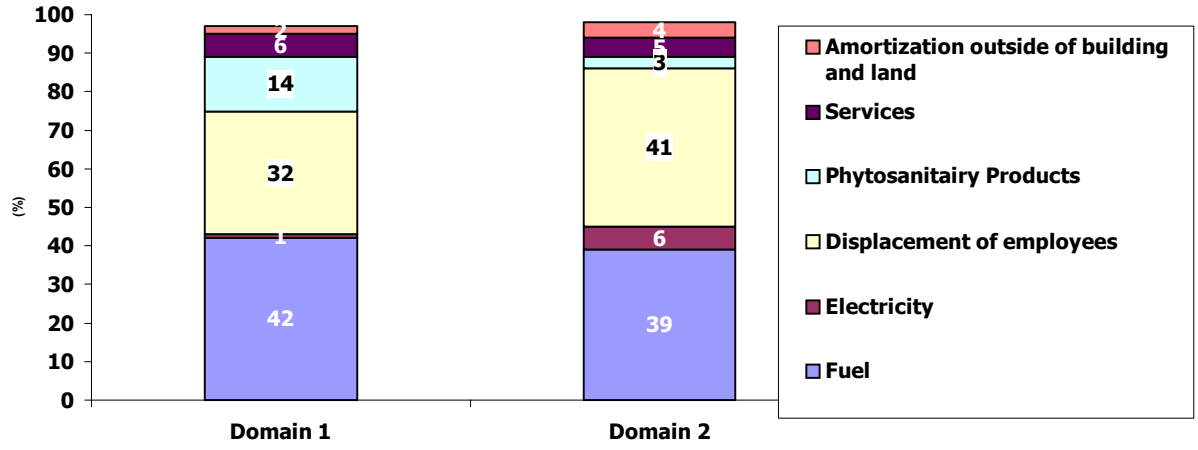
It is specified that viticultural tractors are considered as production tools; and in consequence, the fuel needed for their functioning is considered as internal energy.
The two Carbon Balance® completed specifically for the viticultural production permitted for the obtaining of emission factors for the grape **(table 3).**

	Domain 1	Domain 2
Total Emissions (T.eq.CO_2)	166,421	415,489
Emissions per exploited hectare (T.eq.CO_2 / ha)	3,375	3,360
Emission Factor (kg.éq.CO_2 / tonne)	**413**	**525**

Table 3 : results of the Carbon Balance® "Viticultural Production" and emission factors for the « Grape » input

Only the most significant sources are shown in **graph 3.**

Graph 3 : greenhouse effect contribution for different activities of the viticultural production (%)



On the first hand, it must be noted that the 6 sources total in themselves 97 to 98% of the emissions.
It appears that two activities can be noticeably distinguished from the others:
- the activity « fuel » represents around 40% of the total emissions ;
- The activity « displacements of employees » represents 30 to 40%, this activity is high due to the recruitment of temporary personnel assigned to the manual collecting of grapes in the harvest period (even at times by air transport), as well as the displacements by plane linked with the representation and promotion of the domains, mainly overseas.

3.2.2. Transformation

The part called « transformation » takes into account the sum of the operations from the reception of the grapes up to the shipping of the final product.

Though a specific emission factor was calculated for the “grape” input for the two of the domains, a more global approach was necessary for the 3 other domains.
The results obtained for each of the 5 domains show once again large discrepancies **(table 4)**

	Domain 1	Domain 2	Domain 3	Domain 4	Domain 5
Global Carbon Balance® ($T.eq.CO_2$)	372,135	773,135	236,385	942,760	292,233
Carbon Balance ® ($kg.eq.CO_2$ / hl)	120	132	158	171	115
Carbon Balance ® ($g.eq.CO_2$ / UB)	1163	1189	1248	1481	1112

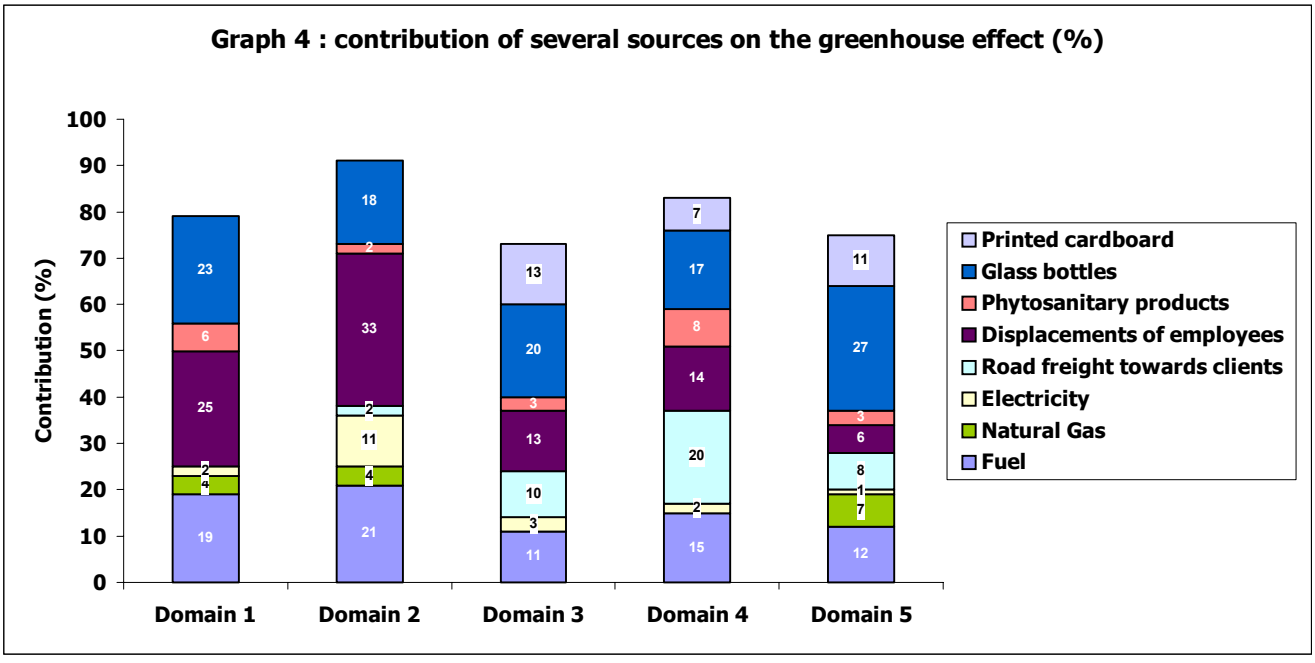
Table 4 : Carbon Balance ® according to the characteristics of the domains.

The Carbon Balance® of the domains 1 and 2 show that the contribution of the primary matter “grape” is very important:
- 44,7% of the Carbon Balance® for domain 1;
- 53,7% of the Carbon Balance® for domain 2.

3.3.3. Global synthesis

Seuls les postes les plus significatifs sont repris dans le **graphe 4**.

Only the most significant sources are shown in **graph 4**



8 sources represent in themselves 75 to 90% of the emissions.

It appears for the five domains, that the three most significant sources are the following:
- Use of glass bottles
- Consumption of fuel for the functioning of viticultural tractors
- Displacements of people

The domains 1 and 2 have fairly similar profiles; two other sources present the same importance:
- The displacements of employees: as for mentioned, the harvest is exclusively by hand and a large number of harvesters is necessary (some coming from overseas, even by plane); displacements of employees overseas by plane.
- A low road freight towards clients (limited taking in charge, important shipping freight)

The domains 3, 4 and 5 also have similar profiles:
- The road freight towards clients is significant; contrary to the other two domains, who transport their products towards shipping platforms located in proximity (limited taking of charge of the client freight by the domains), the domains 3, 4 and 5 keep at their charge the entirety of the freight, mainly by trucks for what regards the shipments over the whole European continent;
- The use of printed cardboard for the packaging of bottles.

Certain sources which were accounted revealed negligible, or no, impact on the Carbon Balance®. These are the following :
- CO_2 outside of energy : it serves mainly for making inert the bottling equipment; this CO_2 can be, in practice, replaced by nitrogen, which does not have an impact on the greenhouse effect;
- Displacements of the employees by train: inexistent or no impact. This transport mode could be an alternative to displacements by automobile, or even by plane for certain displacements;
- Use of plastics, including flexible films ;
- yeasts : no impact due to the low quantities used for vinifications ;
- Products used in oenology : of mineral or organic origin, their restricted manufacturing impact gives them low emission factors (CIVC – JM Jancovici ; 2003) ; in addition, taking into account the small quantities used per hectoliter of wine produces, their contribution is negligible;
- cork (stoppers) : negligible due to the low weight and low emission factor ;
- Printed paper (labels and back labels) : low contribution because of a low quantity per Bottle-Unit (at the level of grams)
- Direct wastes : the field of valorization (material or thermal) being mainly favoured, the waste management has a negligible impact;
- Used water: the water of the domains being purified (communal purification stations or on site), means the disposal in a natural environment has a minimal impact in terms of the BDO5 (Biochemical Demand of Oxygen during 5 days); in consequence, the contribution of used water is negligible.

3.3.4. Discussion

Different conclusions on the impact of the viti-viniculture field with regards to emission of greenhouse gases can be stated:
- the practices (viticultural, oenological, commercial, …) of each domain does not permit for the definition of a unique exploitation typology; furthermore, the climatic and parasitic conditions in the vines can considerably influence, the viticultural practices (more phytosanitary products used, more tractor passages hence, more domestic fuel consumed, …), but also the grape yield, either the volume of vinified wine (thermal regulation of tanks) or the amounts of bottles (impact of packaging)
- Many sources impact in a significant manner the balance: the fuel (for viticultural tractors), the use of glass bottles for the packaging of wine and the home-work routes, notably in the case where the grapes are hand-harvested (more important call for seasonal hand-labourers who need to make frequent displacements on the exploitation sites.)
- according to the equipment or the thermal isolation of the buildings, the contribution of the source “electrical energy” can be either low (2 to 3% of the total emissions), or more significant (11% for domain 2);
- The conception and isolation of buildings have a great influence on the energy necessary for air-conditioning ;
- the prestige of the domains and the markets which are more or less distant, lead to frequent and far displacements via plane, as well as freight towards distant clients;
- the use of wood cases rather than printed cardboard for the packaging of bottles has a very important impact on the Carbon Balance® of a domain via a major decrease of emissions (emission factor for wood is null); the supplier freight can though be increased for wood cases, due to the volume to be transported;

- the total taking in charge of shipments can generate important emissions when road freight is favoured ;
- numerous sources are negligible (inerting CO_2, fermentation yeasts, oenological products, use of cork stoppers, …);
- An optimized management of wastes and used water make these sources negligible.

2.4. Propositions for means of reduction

Many means of reduction can be put forward. Among these are:
- the recuperation and caloric valorization, in a classic furnace, of pruned wood and frames represent a non negligible source of renewable energy (2 to 3,7 millions of tons of wood per year), 1 liter of fuel being equivalent to 3,1kg of dried branches;
- The CO_2 liberated by fermentations is estimated at around 0.5 million of T.eq. CO_2, being 0.1% of the national emissions; the technico-economic interest of its recuperation, stocking or valorization (for example, as bicarbonate) remains to be determined;
- Reasoned technical viticultural itineraries permit for the lightening of treatment programs for plant production: limiting the intervention on parcelles allows for the decreasing of applied phytosanitary products, but in particular of the fuel consumption of viticultural tractors.
- The use, even partial, of biofuels could be an alternative to the consumption of fossil fuels ;
- the glass used for the packaging constitutes another important source ; the reduction of these emissions rests in making the bottles lighter (several tens of grams less per bottle would permit for the reduction of the Carbon Balance® of a domain by several T.eq.CO_2), or even substituting glass by other materials;
- favouring the train over the automobile or plane and encouraging car pooling, as best possible, permits the diminution of emission linked with the home-work routes and the displacements of employees for professional purposes;
- replacing, even partially, the packaging in cardboard by wood cases, of which the emission factor is null, decreases the « printed cardboard- packaging » source ;
- substituting road transport of produced merchandise by other alternative means, such as rail, reduces the emissions associated with transport towards clients;
- favouring the use of wood pickets, rather than galvanized steel pickets creates another sink, due to the use of wood. The use of barriques follows the same logic under the condition that there is an optimization of the valorization of the barrique at the end of their life cycle.;
- favouring nitrogen over carbon dioxide for the inerting ;
- limiting the emissions generated by long transportations ;
- cork, a natural material with contributes to the maintenance of a forest (carbon sinks), contributes generally to limit the impact on the greenhouse effect in comparison to synthetic stoppers or screw caps.

Conclusion

Most international experts agree to underline that the further climate changes will be directly dependant on anthropogenic outputs of greenhouse gases.

The limiting of greenhouse gases applies to all human activities. The viti-viniculture field, of which the terroirs will be directly affected by the climatic evolutions, must integrate itself into the current trend of controlling greenhouse gas emissions.

This first study completed on 5 wineries permitted for the identification of the emission level in this field (around 1100 to 1500 grams of CO_2 equivalents per bottle) which corresponds to several kilometers driving an automobile (100 to 300 grams of CO_2 equivalents per kilometer depending on the model).

The means of reduction of the greenhouse effect depend directly on the conception and installation, of internal organizations and technical viticultural itineraries.

It appears desirable that the different viticultural regions try and integrate this thematic in the governance of their appellations.

After having defined a typology of different exploitations (size, conception and equipment, viticultural system, elaboration process), an initial state should be established using the measurements taken in different representative exploitations. Also, on the basis of the objective to

reduce greenhouse gases on a medium term, means of limiting wastes and valorization methods should be formalized. This approach also entails a progressive quantification of the different viticultural or oenological inputs and funds.

References

- www.ademe.fr
- www.ecologie.gouv.fr
- www.industrie.gouv.fr
- www.effet-de-serre.gouv.fr
- www.journaldelenvironnement.net
- « Histoire du climat et viticulture ; 1ère partie : fondement du climat » ; J. Rochard & A. Srhiyeri – ITV France Epernay ; Revue des Œnologues – n° 116 – juillet 2005 – pp.48-51
- « Traité de viticulture et d'œnologie durables » ; J. Rochard ; collection Avenir Œnologie
- "Gaz à effet de serre : les émissions liées à l'élaboration et à la commercialisation des vins de Champagne" ; A. Descôtes, D. Moncomble ; Services Techniques du CIVC ; La Revue Française d'Œnologie ; juillet-août 2005 ; n° 213 ; pp. 4-7
- "Bilan Carbone : une vision globale des émissions de gaz à effet de serre" ; S. Padilla (ADEME), C. Guyard (Technoscope) ; Environnement et Technique ; décembre 2005 ; n° 252 ; pp. 39-43
- "De la parcelle à la chaudière : valorisation des bois de taille" ; Chambre d'agriculture du Gard, Fédération Départementale des CUMA du Gard ; présentation orale ; 15 mars 2007
- "Viticulture et effet de serre – partie 1/2 : mécanisme et enjeux" ; S. Kerner, J. Rochard ; Institut Français de le Vigne et du Vin (ENTAV / ITV France) ; La Revue des Œnologues; n° 125 ; octobre 2007
- "Viticulture et effet de serre – partie 2/2 : quantification et pistes de réduction des émissions de gaz à effet de serre" ; S. Kerner, J. Rochard ; Institut Français de le Vigne et du Vin (ENTAV / ITV France) ; La Revue des Œnologues ; n° 126 ; janvier 2008