Are current agrofuels a valid tool to tackle climate change ? An assessment of French and British “biofuel” policies

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Title	**Are current agrofuels a valid tool to tackle climate change ? An assessment of French and British “biofuel” policiese.**
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Summary

In this thesis, the wording “biofuel” was determined to be inaccurate and misleading. The wording “agrofuel” was preferred for being more neutral and appropriate. This research investigates whether current liquid agrofuels are a valid tool to tackle climate change. Although agrofuels are often promoted for their potential to reduce greenhouse gas (GHG) emissions compared to fossil fuels, it was found that only a fraction of their direct GHG emissions are usually taken into account. Their indirect land-use change (iLUC) GHG emissions are poorly understood even though they might offset all expected direct GHG benefits while their non-iLUC indirect GHG emissions are always ignored. Methodologies in Lifecycle Assessments (LCAs) were found to be subjective because they contain lots of bias and rely on numerous assumptions. It was also shown that agrofuels’ non-GHG impacts are poorly comprehended. Agrofuel certification schemes were assessed as not being stringent enough to ensure that certified agrofuels bring any environmental benefit compared to fossil fuels. Certification schemes rarely acknowledge uncertainty and tend to have an oversimplified perception of agrofuels’ environmental impacts. Moreover, certification cannot encompass the fact that agrofuels’ iLUC will increase if the consumption of land-intensive foods such as meat and dairy also increases and that agrofuels’ rapid development is not sufficient to compensate for the increase in global oil demand for transport. Though under the same European directives, France and the UK have developed radically different agrofuel policies, which were found to be justified by very different “scientific” results. The challenge posed by iLUC was found to be important enough to decrease UK agrofuel blending targets while French official LCAs confirmed that French agrofuels bring significant GHG benefits. The relative British transparency may actually be used as a pretext to avoid costly agrofuel imports while the French bias may be used to promote French agriculture. 4

Results

Cf les principales conclusions présentées dans le travail de thèse (dont certaines mériteraient sûrement d’êtres rediscutées et reprécisées).

Chapter 6 : Conclusions and recommendations

"Despair is the conclusion of fools."
Benjamin Disraeli (1804-1881), British Prime Minister and writer
"The biggest impediment to action against climate change is no longer climate change denial. It is greenwash !"
George Monbiot, Guardian columnist, Imperial College CEP Seminar Series, 15th February 2007

6.1 Summary of the main findings and contributions of this thesis

This section presents the main findings of this research, which are considered to add up to new knowledge in the agrofuel area.

From chapter 2 :

The wording "biofuel" is inappropriate and misleading for most current transport liquid biomass-derived fuels. The wording "agrofuel" was found to be more neutral and more adequate for such fuels.

Greenwashing arguments and terminology are commonly used by stakeholders from the concerned industries but also in the politics for the promotion of agrofuels.

Although it is recognised that only the agroethanol share is "renewable" in agro-ETBE and agro-MTBE, agrodiesel is often assumed to be 100% "renewable" even though about 11% of its mass usually come from fossil-fuel derived methanol.

The terminology "renewable" seems inappropriate to describe agrofuels as regards the way they are currently obtained.

From chapter 3 :

Agrofuels usually are a small output from their production chains.

Agrofuels' environmental impacts are numerous : direct primary, secondary and tertiary ; indirect linked to iLUC and not linked to iLUC, and affect all environmental areas of concern, not only GHG emissions.

Several official data on transport GHG emissions consider that agrofuels' GHG emissions are equal to zero in transport, not because agrofuels are GHG-neutral but because they attribute their GHG emissions to other sectors than transport.

For most agrofuels, there are serious doubts that GHG benefits are brought compared with fossil fuels when iLUC is taken into account or even if it happens that the actual N_2O emission factor is higher than that currently used in calculations.

The assessment of indirect land-use change associated with a specific land for agrofuel production is highly uncertain.

Many factors already put pressure on land use, such as the growing world population, increasing meat and animal product consumption (which are more land-intensive than vegetable products in general), desertification, urban sprawl, cropland soil exhaustion, etc. Agrofuels are a new factor that adds up to other types of pressure on land use.

Indirect impacts of agrofuels other than iLUC GHG emissions are so far ignored.

From chapter 4 :

Agrofuels' certification schemes capture only some direct environmental impacts of agrofuels (direct secondary and tertiary are not taken into account). Such oversimplification of agrofuels' environmental impacts gives irrelevant results for their actual environmental balance.

Agrofuels' certification schemes are not stringent enough for most certified agrofuels to have low direct non-GHG environmental impacts. Thus, agrofuel certifications may sometimes appear as a means to legitimise intensive unsustainable farming practices.

Agrofuels' GHG emission default values or GHG emission reduction targets in agrofuel certification schemes rely on too many choices and assumptions to be easily compared.

All methodologies for the calculation of agrofuels' GHG emissions rely at some point on methodological bias (choice of co-product treatment, choice of baseline, choice of boundaries, choice of method for the annualisation of LUC GHG emissions, etc.) or assumptions based on uncertain science (choice of N2O emission factor, iLUC GHG emissions, etc.).

The choice of global warming potentials over 100 years (Kyoto Protocol recommendation) seems inconsistent with the choice of annualisation of LUC GHG emissions over 20 years.

Apart from reduction of land needs thanks to changes in consumption patterns and dietary habits of consumers, few solutions seem to prevent current agrofuels from causing iLUC.

Current agrofuels may be seen as an incentive for citizens not to change their personal transportation choices and therefore habits.

In most cases, agrofuels' potential direct GHG benefits are currently only possible if co-products are used as animal feed supposed to displace imported feed (for instance soymeal in Europe). Thus, agrofuels' direct GHG emission reductions are somehow artificially gained from the livestock sector, which is known to already be a major GHG contributor.

According to most scenarios, agrofuels' rapidly increasing consumption will not be sufficient to compensate for the increase in transport energy demand. Thus, agrofuels only add up to growing fossil fuel demand, they do not really substitute for fossil fuels at the world level.

Discussing agrofuels' environmentl sustainability does not make sense when agrofuels are not assessed in the general context of increasing land needs and increasing transport energy demand.

Considering current scenarios of rapid increases in transport energy demand (mostly met thanks to oil consumption), even best theoretical agrofuels (ideal zero-carbon agrofuels) do not allow a reduction in transport's growing GHG emissions.

From chapter 5 :

The RTFO reports make agrofuels' consumption in the UK relatively transparent, with information of agrofuels' consumption by feedstock or by country of origin presented when available. However, the default values used to assess agrofuels' GHG emission reductions do not take account of indirect impacts and are arbitrarily chosen in ways that make some types of agrofuels with specific unreported data have lower default values than those with reported data. The official estimate of average GHG emission reduction enabled by agrofuels consumed in the UK thus appears to be artificially high.

The RTFO is designed in such a way that it incentivises fuel suppliers not to report previous land use when conversion of forest or grassland occurred.

The French authorities increased agrofuel blending targets for France based on extremely favourable GHG emission reductions calculated in a 2002 report of Ecobilan (Ecobilan/PriceWaterhouseCoopers, 2002b). However, this report lacks transparency, contains numerous flaws and methodological biases that favour agrofuels and was not made public in its entirety for nearly 5 years.

French reports to the European Commission on the implementation of the 2003/30/EC Directive are not transparent, contain numerous flaws and overestimate the agroethanol blending by energy content in France because of a wrong choice of LHV for agroethanol contained in agro-ETBE.

There has been no transparency on the origin (feedstock, country of origin or previous land use) of agrofuels consumed in France since 2004.

The latest French reports on agrofuels' GHG emissions used methodological biases that artificially improved agrofuels' GHG balance. In a withdrawn version of the latest 2010 report, fossil fuel GHG intensities were even exaggerated in order to improve agrofuels' GHG emission reduction compared with fossil fuels. Finally, the conclusions of the last official report do not take account of agrofuels' iLUC GHG emissions.

There is little debate on agrofuels' iLUC GHG emissions in France, resulting in a general misunderstanding of this concept. Moreover, some stakeholders of the French agrofuel industry take advantage of this confusion to promote agrofuels from French feedstocks, claiming such agrofuels do not cause iLUC.

The UK agrofuel policy used the pretext of to the evolution of the scientific debate on agrofuels' GHG implications to adapt its policy whereas France did not change its targets.

"Scientific' results on agrofuels" GHG balance are different between France and the UK. They actually match political aims of promoting French agriculture in one case, and of reducing forecast imports of agrofuels in the British case. Thus "science" is dependent on political and economic conditions and used in a biased way for the justification of political objectives.

<u>Overall finding</u> :

While transport GHG emissions are increasing, agrofuels are brought in to reduce transport GHG emissions. However, agrofuels' overall GHG emissions are often comparable to or even worse than those of fossil fuels, not to mention other environmental impacts.

Therefore, agrofuels' increasing consumption may result in a higher increase in transport-associated GHG emissions than if fossil fuels continued to be used (nearly) alone. Due to increasing transport energy demand, even if agrofuels were GHG-neutral, they could at best only partly reduce the increase in transport GHG emissions.

Thus, agrofuels can be seen as a massive "red herring" to transport GHG emissions.

Deliverables

Manuscrit de la thèse

Papers and Publications

The following presentations and publications written or co-authored by the author are directly related to this thesis :

Mercier, J. & Gathorne-Hardy, A. (2010) Why such differences between the French and British agrofuel policies ? Oral presentation given at the *18th European Biomass Conference*, 3rd - 7th May 2010, Lyon, France.

Mercier, J. & Gathorne-Hardy, A. & Makuch, Z. (2009) Can biofuels justify current transport policies ? Oral presentation given at the *Climate Change - Global Risks, Challenges & Decisions* Congress, 10th - 12th March 2009, Copenhagen, Denmark.

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Woods, J. & Mercier, J. (2007) *Sustainability Criteria for Biofuels*. Econsense. Berlin, Germany, p.61-67, [Online] Available from here [Accessed 25th January 2011]

Mercier, J. & Makuch, Z. (2007) Key elements for the development of a sustainability certification of biofuels. In: *15th European Biomass Conference*, 7th - 11th May 2006, Berlin, Germany, pp. 3019-3021.

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Are current agrofuels a valid tool to tackle climate change?

An assessment of French and British 'biofuel' policies

by

Jérémie Mercier

A thesis submitted for the degree of Doctor of Philosophy of the University of London

July 2011

Declaration of own work

I declare that this thesis:

“Are current agrofuels a valid tool to tackle climate change? - An assessment of French and British ‘biofuel’ policies”

is entirely my own work and that where any material could be construed as the work of others, it is fully cited and referenced and/or with appropriate acknowledgement given.

Signature:

Name of student: Jérémie Mercier
Name of supervisor: Mr Zen Makuch

Abstract

In this thesis, the wording ‘biofuel’ was determined to be inaccurate and misleading. The wording ‘agrofuel’ was preferred for being more neutral and appropriate. This research investigates whether current liquid agrofuels are a valid tool to tackle climate change.

Although agrofuels are often promoted for their potential to reduce greenhouse gas (GHG) emissions compared to fossil fuels, it was found that only a fraction of their direct GHG emissions are usually taken into account. Their indirect land-use change (iLUC) GHG emissions are poorly understood even though they might offset all expected direct GHG benefits while their non-iLUC indirect GHG emissions are always ignored. Methodologies in Lifecycle Assessments (LCAs) were found to be subjective because they contain lots of bias and rely on numerous assumptions. It was also shown that agrofuels’ non-GHG impacts are poorly comprehended.

Agrofuel certification schemes were assessed as not being stringent enough to ensure that certified agrofuels bring any environmental benefit compared to fossil fuels. Certification schemes rarely acknowledge uncertainty and tend to have an oversimplified perception of agrofuels’ environmental impacts. Moreover, certification cannot encompass the fact that agrofuels’ iLUC will increase if the consumption of land-intensive foods such as meat and dairy also increases and that agrofuels’ rapid development is not sufficient to compensate for the increase in global oil demand for transport.

Though under the same European directives, France and the UK have developed radically different agrofuel policies, which were found to be justified by very different ‘scientific’ results. The challenge posed by iLUC was found to be important enough to decrease UK agrofuel blending targets while French official LCAs confirmed that French agrofuels bring significant GHG benefits. The relative British transparency may actually be used as a pretext to avoid costly agrofuel imports while the French bias may be used to promote French agriculture.

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- Mercier, J. & Makuch, Z. (2007) Key elements for the development of a sustainability certification of biofuels. In: *15th European Biomass Conference*, 7th - 11th May 2006, Berlin, Germany, pp. 3019-3021.

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Acronyms and abbreviations

ADEME	*Agence de l'environnement et de la maîtrise de l'énergie* (French Environment and Energy Management Agency)
ALCA	Attributional Life Cycle Assessment
AR4	IPCC Fourth Assessment Report (of 2007)
ASEAN	Association of South East Asian Nations
BAU	Business as usual
BioIS	Bio Intelligence Service
BioNachV	*Biomasse-Nachhaltigkeitsverordnung* (German Biomass Sustainability Ordinance)
BPU	Biomass Production Unit
BtL	Biomass to Liquid = liquid fuels derived from gasified biomass
C	Carbon
CA	State of California
CH_4	Methane
CLCA	Consequential Life Cycle Assessment
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CONCAWE	CONservation of Clean Air and Water in Europe (European Oil Company Organisation for Environment, Health and Safety)
DDGS	Distillers Dried Grains with Solubles
DEFRA	UK Department for Environment, Food and Rural Affairs
DfT	UK Department for Transport
DGEC	*Direction Générale de l'Energie et du Climat* (French General direction of energy and climate)
DIREM	*Direction des ressources énergétiques et minérales* (French direction of energy and mineral resources)
EC	European Commission
EDEN	*Energie en Normandie* (French environmental NGO)
EEA	European Environment Agency
EF	Emission Factor
EPA	United States Environment Protection Agency
EPFL	*Ecole Polytechnique Fédérale de Lausanne*
ETBE	Ethyl *tert*-butyl ether
EU	European Union
FAME	Fatty Acid Methyl Ester

FAO	Food and Agriculture Organization of the United Nations
FFB	Fresh Fruit Bunches
FNE	*France Nature Environnement* (French environmental NGO)
GBEP	Global BioEnergy Partnership
GHG	Greenhouse Gas
GM(O)	Genetically Modified (Organism)
GWP	Global Warming Potential
ha	hectare
HCV	High Conservation Value
ICE	Internal Combustion Engine
IEA	International Energy Agency
IFOAM	International Federation of Organic Agriculture Movements
IFP	*Institut Français du Pétrole* (French Petroleum Institute)
iLUC	Indirect Land-Use Change
INRA	*Institut National de la Recherche Agronomique* (French National Institute for Agricultural Research)
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JRC	European Commission Joint Research Centre
km	kilometre
L	litre
LCA	Life- Cycle Assessment
LCFS	Low Carbon Fuel Standard
LHV	Lower Heating Value
$LowC^{VP}$	Low Carbon Vehicle Partnership
LUC	Land-Use Change
M	mega (million)
MJ	megajoule
MPOC	Malaysian Palm Oil Council
MS	Member State(s) of the European Union
MSW	Municipal Solid Waste
Mtoe	Megatonne of oil equivalent (1 Mtoe = 1 million tonnes of oil equivalent)
MTBE	Methyl *tert*-butyl ether
N	Nitrogen
N_2O	Nitrous oxide
NGO	Non Governmental Organisation
NL	The Netherlands
NO_x	Nitrogen Oxides

N-P-K	Nitrogen-Phosphorus-Potassium
OECD	Organisation for Economic Co-operation and Development
OFGEM	UK Office for Gas and Electricity Markets
ONIGC	*Office National Interprofessionnel des Grandes Cultures* (French Interprofessional Office for Main Crops)
OSR	Oilseed Rape
POME	Palm Oil Mill Effluent
POP	Persistent Organic Pollutant
RAC-F	*Réseau Action Climat France* (French environmental NGO)
RED	"Renewable Energy Directive" = Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources
RFA	Renewable Fuels Agency (UK) or Renewable Fuels Association (US)
RFS	Renewable Fuel Standard
RME	Rape(seed) Methyl Ester
RSB	Roundtable on Sustainable Biofuels
RTFO	Renewable Transport Fuel Obligation
SAR	IPCC Second Assessment Report (of 1995)
SB	Sugar beet
SF	Sunflower
SOM	Soil Organic Matter
SVO	Straight Vegetable Oil
TAR	IPCC Third Assessment Report (of 2001)
toe	tonne(s) of oil equivalent
UBET	Unified Bioenergy Terminology
UC	University of California
UFIP	*Union Française des Industries Pétrolières* (French Union of Petroleum Industries)
UK	United Kingdom of Great Britain and Northern Ireland
UN	United Nations
UNEP	United Nations Environment Programme
UNICA	*União da Indústria de Cana-de-Açúcar* (Brazilian Union of the Sugarcane Industry)
US or USA	United States of America
VOC	Volatile Organic Compound
WEO	World Energy Outlook
WTT	Well-To-Tank
WTW	Well-To-Wheel
WWF	World Wide Fund for Nature

Chapter 1:
Background and introduction

"I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait 'til oil and coal run out before we tackle that."
Thomas Edison (1847-1931), American inventor

1.1 Background

Humanity's agenda is fraught with environmental crises:

- anthropogenic greenhouse gas (GHG) emissions that are thought to cause global warming (2007b) are increasing at a higher pace than anticipated (Lydersen, 2009);
- global biodiversity is thought to be collapsing. Some even consider that we are in the midst of the sixth mass extinction (Wake & Vredenburg, 2008);
- a water crisis in terms of access to clean drinking water and adequate sanitation for many people worldwide (World Water Council, 2010) while at the same time water resources are increasingly scarce in numerous countries (Mercier, 2005);
- a food crisis (Nellemann *et al.*, 2009). After a record figure of 1 billion people in 2009, 925 million people suffer of malnutrition worldwide today (World Hunger Education Service, 2010);
- mechanised agriculture is exhausting at an alarming rate humanity's most essential resource that is soil (Montgomery, 2007).

On top of these fears, peak oil which may well have already happened (IEA, 2010) might lead to radical changes in our current economies that are based on cheap oil (Industry Taskforce on Peak Oil & Energy Security, 2010).

Because of the threats posed by climate change, the likely end of cheap oil and the numerous crises that humanity is about to face, many hope that renewable carbon-neutral low-impact fuels can soon replace current (carbon-intensive, probably increasingly polluting and expensive in the near future) fossil fuels for transport.

Indeed, the transport sector is a significant and growing contributor to greenhouse gas emissions and it is 95% dependent on oil (OECD/ITF, 2008).

However, the only 'non-fossil' fuels that are readily available on a rather important scale in current car engines and at reasonable prices are liquid transport fuels made from biomass, usually called 'biofuels'. Current 'biofuels' can be divided into two main categories:
- ethanol (usually called 'bioethanol') is a substitute for petrol and is made from sugar crops (sugar cane and sugar beet) or starch crops (maize and wheat);
- fatty acid methyl ester (FAME) (usually called 'biodiesel') is a substitute for diesel and is made from oilseed crops (rapeseed, soybeans, palm trees, coconut, sunflower, etc.), from tallow and to a smaller extent from waste vegetable oils.

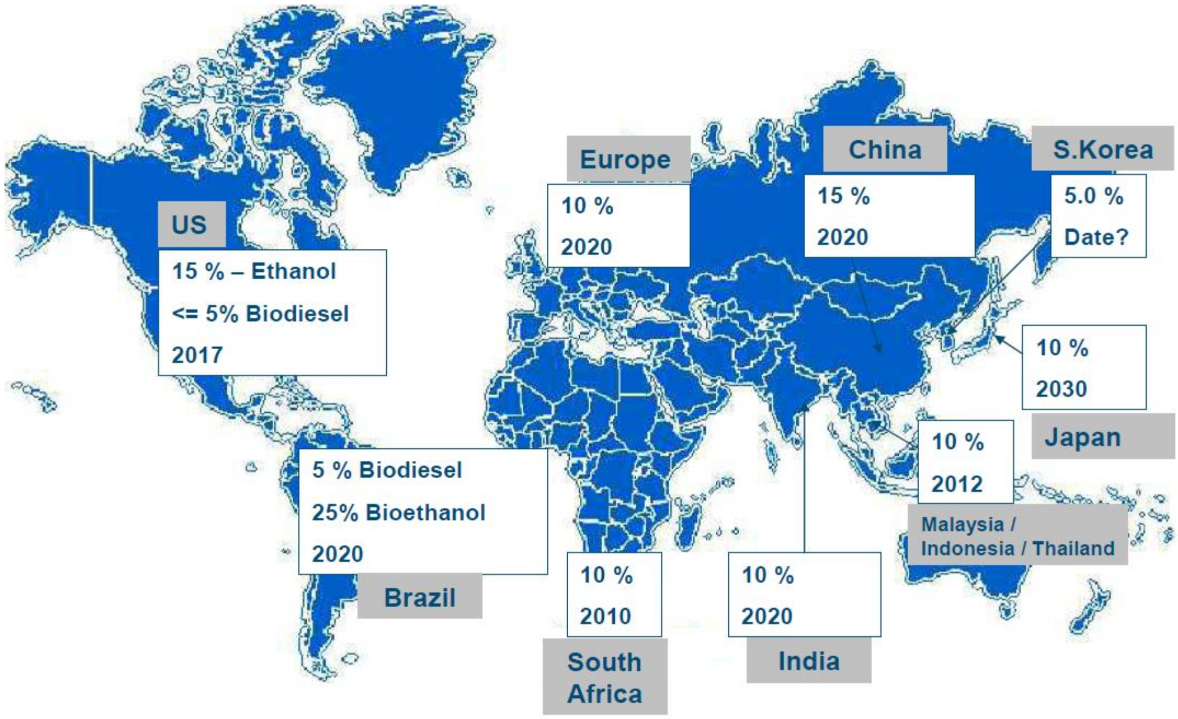
Since the mainstream terminology will be demonstrated to be misleading and confusing (cf. chapter 2), the more appropriate terminology 'agrofuels', 'agroethanol' and 'agrodiesel' will be used throughout this thesis.

A working paper from the World Bank (Rajagopal & Zilberman, 2007) identified "seven reasons for the excitement surrounding [agro]fuels:
- [agro]fuels are replenishable;
- [agro]fuels can reduce carbon emissions;
- [agro]fuels can increase farm income;
- [agro]fuels can improve energy security;
- [agro]fuels can create new jobs;
- [agro]fuels have physical and chemical properties similar to oil;
- [agro]fuels are simple and familiar".

Expanding the use of agrofuels is also thought by some to support energy security objectives in that they displace petroleum fuels while agrofuels' physical properties might also improve transport fuel qualities by boosting fuel octane (IEA, 2004).

Thus a growing number of countries have set mandates on agrofuel blending in total transport fuels (REN21, 2010). Some of the most important mandates can be seen in the following figure:

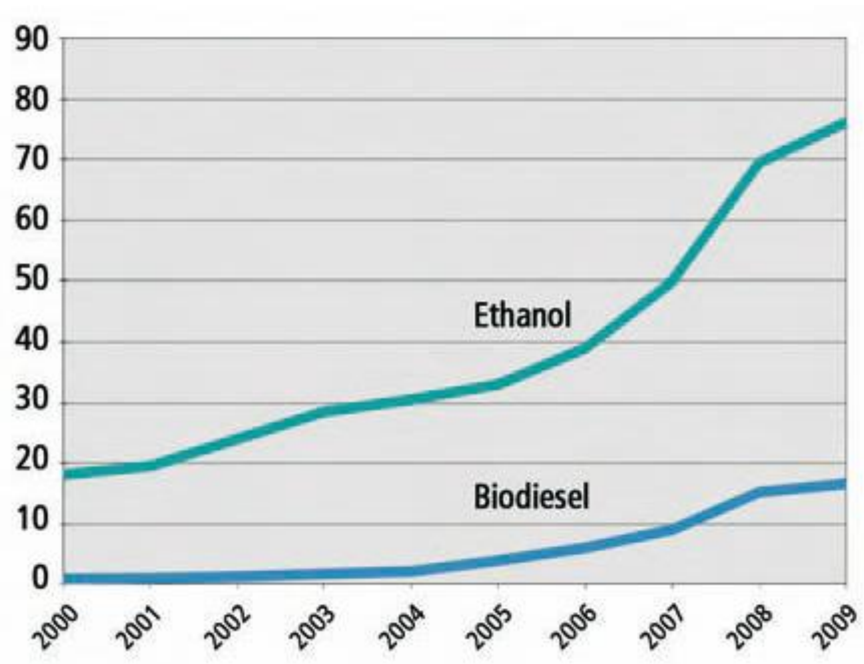
Figure 1: Agrofuel mandates worldwide



Source: (Banse, 2008)

Due to these favourable policies, agrodiesel and agroethanol production (and consumption) have increased phenomenally in the last decade (cf. following figure):

Figure 2: Agroethanol and agrodiesel production between 2000 and 2009 (in billion litres)



Source: (REN21, 2010)

Despite these impressive curves, it should be noted that today's consumption of agrofuels currently amounts to only a few percent of total transport fuels by energy content (REN21, 2010).

Although originally described as contributors to the objective of an "environmentally-friendly security of supply" (European Commission, 2003), agrofuels soon became a highly controversial topic regarding the potential direct adverse impacts they could have on the environment. Thus, non-governmental organisations (NGOs) such as the World Wide Fund for Nature (WWF) asked for a "mandatory, legally binding environmental certification" (WWF, 2006) in order to ensure that agrofuels are made in a 'sustainable' way.

In this context, this research - funded by the French Fondation Tuck, closely linked to the French Petroleum Institute IFP, and funded by four large French companies: Axens, Diester Industries, Renault and Total - was originally aimed at the means to implement an international environmental certification scheme for agrofuels.

However, the growing debate on agrofuels' environmental impacts accelerated international research on what types of environmental criteria should be put in place in such certification schemes (Cramer *et al.*, 2006; European Commission, 2006; Fritsche *et al.*, 2006; DfT, 2007; Roundtable on Sustainable Biofuels, 2007a). Moreover, the debate on agrofuels' environmental impacts was suddenly given increasing media coverage as agrofuels started to be accused of fuelling deforestation (Metro, 2007) and hunger (Ferrett, 2007) by increasing pressure on food prices.

Finally, the GHG benefit of agrofuels – which is the main official reason for their promotion – was challenged by studies claiming that agrofuels could be more GHG intensive than fossil fuels when their indirect impacts on land use change were taken into account (Fargione *et al.*, 2008; Searchinger *et al.*, 2008). These new inputs to the debate on agrofuels' 'sustainability' even influenced agrofuel policy in the UK (RFA, 2008b).

In such a context, the research could not be continued without fundamentally changing direction in order to keep up with the rhythm of the debate. The subject of this thesis needed to be updated to be more relevant. It was thus decided that the research would eventually consist of an interdisciplinary investigation on the validity of the promotion of agrofuels on environmental grounds.

1.2 Aim and objectives

<u>Research problem</u>:

Numerous policies have been promoting agrofuels largely on environmental grounds. However, agrofuels' overall environmental impacts are not very well understood. Moreover, there is no single methodology to calculate direct GHG emissions and, as we shall see, most policies have tended to ignore indirect GHG emissions associated with indirect land-use change (iLUC) thus far. Finally, in the current context of an increase in transport energy demand, agrofuels can look more like a complement to fossil fuels than a true substitute.

<u>Aim</u>:

This research aims at **determining whether the promotion of agrofuels on environmental grounds is legitimate**.

Two case studies have been selected to illustrate this research: the French and the British agrofuel policies. These case studies are particularly interesting because both countries are following the same European Directives on agrofuels promotion but their agrofuel consumption profiles as well as their political approaches are very different.

So far, most policies that promote agrofuels have looked at them with a rather simple view. Most of the time, they only discuss some potential environmental impacts (with a large focus on GHG emissions) and then claim that the competition over food production and indirect effects need to be assessed.

Such regimes have not succeeded in considering agrofuels as part of a more complex system at the interface between agriculture (which includes food production, land use, etc.) and transport that both have considerable environmental impacts. They also tend not to challenge consumers' habits apart from the provision of agrofuels directly blended with fossil transport fuels.

<u>Objectives:</u>

The main objectives of this research are the following:

- examine the wording used for the promotion of current liquid transport biomass-derived fuels, particularly the term 'biofuel' and identify more appropriate and neutral wording;
- discuss agrofuels' renewability;
- produce a comprehensive framework of potential environmental issues directly and 'indirectly' linked to agrofuels and show the complexity of agrofuels' environmental implications;

- compare selected agrofuel certification schemes, provide a critical review of their 'sustainability standards' and identify gaps in certification;

- identify methodological bias in GHG life-cycle assessments (LCAs);

- assess the interest of selected agrofuels encouraged for their presumed higher environmental benefits;

- analyse indirect Land-Use Change (iLUC) and determine how agrofuels' related iLUC could be reduced;

- assess the potential negative side-effects of certification as well as the opportunity for the raising of awareness in the context of the agrofuel debate;

- put current agrofuels in today's context of growing road transport energy demand in order to assess their 'sustainability' potential;

- provide a critical assessment of the British and French agrofuel policies, compare the ways agrofuels are presented by officials in France and in the UK, and compare how both countries take potential environmental impacts of agrofuels into account in view of the evolving debates;

- in the interest of better regulating agrofuels, identify future research needs pertaining to the assessment of agrofuels' actual environmental implications.

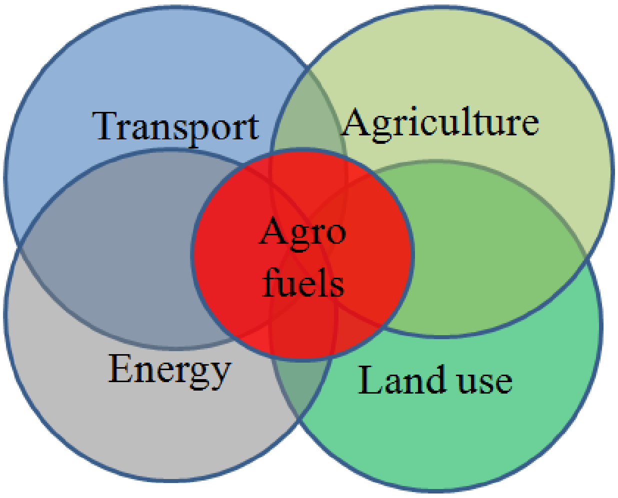
1.3 Scope

In order to limit the research to the most representative agrofuels in today's world, it was decided to focus on the two main current road transport liquid fuels made from agriculture crops:

- agroethanol obtained after the distillation of the broth resulting from the fermentation of sugars coming either from sugar crops or from hydrolysed starch from starch crops;
- agrodiesel obtained after trans-esterification of vegetable oil with methanol.

The scope of this PhD is interdisciplinary by essence. Indeed, agrofuels are at the interface of transport and agriculture and thus raise questions linked to energy as well as land use (cf. following figure), which both have strong implications on the environment, particularly in relation to GHG emissions.

Figure 3: Agrofuels at the crossroad of transport, energy, agriculture and land use



Source: Personal figure

Thus, numerous elements of science (science of climate change, of soil, of agriculture, basic thermodynamics, etc.) had to be understood and integrated into this research and then placed in the context of policies promoting agrofuels.

As agrofuels are commonly promoted for their environmental benefits and particularly their GHG benefits, it was decided to focus on agrofuels' GHG emissions even though other environmental impacts could not be entirely put aside and are thus listed and described in chapter 3. Such a review of agrofuels' potential environmental implications was thought to be necessary even though it was not possible to go too deeply into our investigation of non GHG-related environmental impacts. Oilseed rape, which is the main agrodiesel feedstock in Europe, was chosen as a basis for the presentation and listing of agrofuels' potential environmental implications.

Numerous countries worldwide have integrated agrofuels as part of their transport and environment policies. But to illustrate our research, it was chosen to be more Europe-centric and to particularly focus on the agrofuel policies of two close countries under the same European Directives but with radically different views on agrofuels: France and the UK.

It was also chosen not to deal with economics of agrofuels but to stay in the field of the perception of their environmental impacts in the policy arena.

1.4 Summary of approach and methods

Data and concepts in this thesis mostly come from an extensive literature review of reports, scientific articles, conference proceedings, books and selected websites. As a large part of this thesis is the result of a literature-review based research, it was thought that an introductory 'literature review' section would be of little relevance, the literature review being made all along the thesis.

Rapidly after the beginning of this research - the first aim of which was to analyse how an international environmental certification scheme for agrofuels could be developed - it clearly appeared that agrofuels were an increasingly controversial subject. Thus the initial research project had to be re-evaluated. At the time, lots of work was undertaken by numerous organisations on agrofuel certification, but it seemed that an insufficient amount of academic work was undertaken on the criticism of agrofuel certification schemes and agrofuels in general. Indeed, the main narrative that was promoting agrofuels on environmental grounds seemed to be increasingly in contradiction with the growing scientific evidence that environmental impacts previously not taken into account (such as indirect land-use change or an increased N_2O emission factor for instance) could negate all chance of GHG emission reduction for most agrofuels.

Due to the rapidly moving ground of the debate on agrofuels' environmental impacts, a constant vigilance vis-à-vis the new findings in agrofuels' environmental impacts and their repercussions in policies was needed.

The debate was found to be complex not only because of the inherent complexity of agrofuels' range of environmental impacts but also in part because some of the wording commonly used in the debate was not thought to be appropriate or accurate. This research endeavours to use more objectively justifiable wording in order to have a rigorous intellectual progression. Thus, the wording 'biofuel' is challenged from the beginning (chapter 2) because it is thought to bring too much confusion and to considerably polarise the discussion, which reduces the chance of having a sensible debate.

In order to better understand both sides of the debate, the literature review needed to be complemented by the attendance of workshops and conferences (which always raised interesting questions from the audience). Then, the presentation of my findings (which evolved with my understanding of the subject) on five occasions during conferences was of high importance insofar as it always gave me an opportunity to precise my arguments while the

feedback from attendants sometimes helped me understand better the complexity of the agrofuel debate.
Registration at the Roundtable on Sustainable Biofuels in 2007, attendance of their first telephone conference and of their 2009 European meeting in Brussels as well as the attendance of several stakeholder workshops about the British agrofuel policy proved useful to keep up with the progress in the work on agrofuels' environmental certification.

Meetings with different stakeholders (those of the French case study are listed in Appendix B) also proved particularly useful in order to improve my grasp of the subject and thus for the writing of chapters 3, 4 and 5.

Although the energy analysis of agrofuels is very important - particularly when it is done with the concepts of 'net energy' and 'energy return on the investment' (EROI) developed by Georgescu-Roegen in the 1970s - and can bring arguments that challenge the validity of the promotion of agrofuels (Giampietro & Mayumi, 2009), this thesis focuses on the analysis of the discourse that promotes agrofuels with the arguments of their supposed environmental benefits, particularly in terms of GHG emissions. Indeed, at a time when climate change is at the top of the international agenda, agrofuels are largely promoted for their supposed potential to reduce GHG emissions when used instead of their fossil fuel equivalents for transport.
Thus, in order to limit the scope of this PhD as well as for time purposes, it was decided to concentrate on GHG issues of agrofuels. In addition, it should be noted that agrofuels' GHG related emissions are not necessarily linked to energy issues.

As GHG emissions are part of a bigger group of issues ('environmental issues'), and since climate change mitigation is not the only element of environmental policies - which need to be consistent and not decrease some environmental impacts at the expense of others - it was also thought useful to determine what areas of concern other than GHG emissions were impacted by agrofuel production (cf. chapter 3).

Chapter 3 also demonstrates that the environmental issues related to agrofuels' development impact numerous areas of concern and that the scientific understanding of agrofuels' environmental impacts is weak. Such situation where 'facts are uncertain, values in dispute, stakes high and decisions urgent' is a typical situation of the 'post-normal science' theory (Funtowicz & Ravetz, 1991).

The notion of indirect land-use change (iLUC) was given a more rigorous and more general definition than that found in the literature that is found to be usually too vague. To show the complexity of its assessment (and the range of values that can be obtained), several examples of iLUC presented with a bottom-up approach were developed.

Chapter 4 contains the concrete critical appraisal of the corporate narrative about agrofuels. This chapter shows the strong corporate will to 'certify' agrofuels and the common oversimplification of the representation of agrofuels' environmental impacts that generally ignores complexity and does not take uncertainties into account. For this criticism to be performed, GHG and environmental arguments of the main discourse are used throughout the thesis, not in order to legitimise the main discourse, but because it was thought particularly efficient to use the elements and data of the main discourse to highlight its shortcomings and the weaknesses of the supposed evidence of agrofuels' environmental performance.

Within the main narrative, the use of 'scientific' tools such as Life Cycle Assessments (LCAs) - particularly GHG LCAs - is of the the utmost importance. Indeed, results of LCAs giving a lower GHG figure for agrofuels than for fossil fuels are often used as a justification for agrofuel promotion. The idea of generating my own LCA was tempting but performing an LCA is particularly time-consuming and depends on numerous data, which need to be of high quality. Moreover, many agrofuel GHG LCAs have been generated and published, so adding another one was not thought to be particularly useful. Finally, performing an LCA is by itself a discipline, and my aim was not become a full professional specialised in the generation of LCAs. In this thesis, it was thought more useful to use literature to understand the complexity of LCAs but also to pinpoint their weaknesses. Indeed, LCAs may sound like a rigorous and objective tool even though they actually may leave a relatively large space for subjectivity and bias.

The identification of methodological bias inherent to LCAs and of areas for which scientific knowledge is lacking were also identified in chapter 4.

An important shortcoming of policies promoting agrofuels on environmental grounds was identified when scenarios on the evolution of global GHG emissions and global transport energy demand were analysed. Scenarios provided in World Energy Outlooks of the International Energy Agency proved particularly useful to show that even a large increase in hypothetical carbon-neutral agrofuel consumption could not prevent global transport GHG emission from increasing, simply because the increase in transport energy demand is several times higher than what agrofuels could potentially fill in in the best scenarios.

French and British agrofuel policies were chosen as case studies because they promote agrofuels in a very different way even though they implement the same European directives. Thus, their agrofuel consumption profiles as well as the discussions on agrofuels' environmental impacts within their borders are very different from one country to the other.

Since data of agrofuel consumption (by feedstock, by country of origin and to some extent by former land use) were largely available in the UK, they were used (and compiled in Appendix C), analysed and checked in order to see how transparent the British agrofuel policy was. Since numerous British reports on agrofuels' GHG emissions are available, these were extensively analysed in order to determine their strengths and shortcomings. Statistics on UK agrofuel consumption were taken from RTFO (Renewable Transport Fuel Obligation) monthly reports. I also attended and participated in meetings discussing the RTFO at the Department for Transport (DfT) as well as in conferences organised by the RFA (Renewable Fuels Agency), the UKERC (UK Energy Research Centre) and of course by Imperial College. Participation in these conferences gave me the opportunity to develop my understanding of the British debate and follow the latest changes in the British agrofuel policy.

As for the French agrofuel policy, data of agrofuels consumption in France was found to be relatively hard to reach. Data collection of agrofuel consumption in France mainly came from French national reports to the European Commission.

However, no official data on agrofuel consumption by feedstock or by country of origin was available. Only speculations or 'hints' found in some reports or presentations could give some idea of the characteristics of agrofuels consumed in France.

Official data on agrofuel consumption by type (agroethanol, agro-ETBE or agrodiesel) was only available in French reports to the European Commission sent on a yearly basis after the 2003/30/EC directive.

A thorough analysis of the data from these reports revealed that there were some inconsistencies regarding yearly consumptions of agrofuels from one year to another as well as in the calculations of the share of agrofuels in transport fuels by energy content. Investigations were needed to determine what persons were in charge of the reporting of statistics and in the calculations of the energy share of agrofuels in total transport fuels. This was a complex and time-consuming task but I eventually managed to contact the main stakeholders involved in the publication of official agrofuel data. Raw data were obtained and could be used for the calculation of the actual share of agrofuels in total transport fuel (by energy content) and most mistakes in the calculations could be determined.

Since data on the origin of agrofuels consumed in France (by country or by feedstock) were not available, I thought useful to meet and interview stakeholders that were involved in research on agrofuels (both academics and members of NGOs), in the French debate or in environmental consultancy dealing with agrofuels. It was not deemed necessary to perform structured or semi-structured interviews because the aim was not to make a survey but rather to try to complete the French agrofuel puzzle with the missing pieces. Thus, the interviews were not necessarily formal and could be described as ad hoc interviews. Some people contacted could not express their opinion or give data because of administrative or corporate pressure while others could mention unofficial data that seemed to be known by many but could not be made official for political reasons.

A thorough analysis of French reports and a sustained contact with several French stakeholders made possible a follow-up of the French situation and an understanding of the reasons why an official report was made available online only for only few days in 2009, before being withdrawn and eventually republished in a revised version several months afterwards.

Finally, since agrofuels are such a complex and controversial subject, commonsense and a critical mind were extremely useful in order to organise and analyse publications and concepts according to their type: subjective political support or more objective scientific studies.

1.5 Novelty of the research

Although this research mainly focused on agrofuels' GHG emissions, it is probably the first that lists so many environmental impacts associated with agrofuel production.

This research also challenges agrofuels' 'sustainability' - including that of certified agrofuels - in a structured logical way and is one of the first that goes beyond national/regional transport policies and places agrofuels' claims of sustainability in the global perspective of transport energy demand.

It also detects and puts forward examples of influential statistics on transport (from Eurostat and the International Energy Agency) that do not include agrofuels' GHG emissions in transport GHG emissions even though agrofuels' associated GHG emissions might be higher than those of fossil fuels.

It uses a precise and defensible terminology when it is thought that common terminology leads to misunderstanding and risks of confusion.

This research makes the rarely mentioned link between agrofuels' potential iLUC and consumer's dietary habits.

Finally, this thesis is the first that compares the French and British agrofuel policies by providing a critical analysis of British RTFO reports and French reports to the European Commission on the implementation of the 2003/30/EC Directive. It gives the most precise demonstration that French agrofuel policy is based on opacity of data and distortion of the perception of the true environmental impacts of agrofuels consumed in France.

1.6 Outline of the thesis

Chapter 1: Background and introduction

This first chapter sets the scene for the unfolding of this research, by determining the background, context, aim and objectives, methodology and novelty of the research.

Chapter 2: What terminology to describe biomass-derived transport fuels?

The second chapter analyses terminologies used to describe current biomass-derived transport fuels. It highlights the issues related to the wording ‘biofuels’ and proposes the wording ‘agrofuels’ which is thought to be not only more neutral but also more appropriate.

Chapter 3: Agrofuels’ environmental impacts are numerous and poorly understood

The third chapter identifies and describes the complexity of environmental impacts linked to agrofuels that are thought to be worth taken into account in order to have a good understanding of agrofuels’ implications. It not only describes usual impacts on a lifecycle basis but goes beyond this by listing indirect impacts (not only indirect GHG emissions) and other impacts that are often forgotten or ignored. It shows the complexity of iLUC and calculates the amount of indirect land-use change for two examples in a bottom-up approach.

Chapter 4: Certification does not make agrofuels sustainable

The fourth chapter makes a critical comparison of the environmental criteria and GHG emission calculation methodologies of selected agrofuels’ environmental certification schemes. Methodological biases are determined and described in order to show that agrofuels’ calculated GHG emissions are highly subjective and depend on numerous choices and assumptions. The chapter then shows the limits of certification schemes, particularly their apparent inadequacy to deal with agrofuels’ indirect land use change impacts. It also suggests ways to reduce iLUC from agrofuels. Finally, it contextualises agrofuels within world transport energy demand, which challenges the whole idea of agrofuels being potentially ‘sustainable’.

Chapter 5: *Why such differences between the French and British agrofuel policies?*

The fifth chapter compares agrofuel blending targets and declared official blending in France and in the UK after pointing out anomalies found in the French reports to the European Commission on the implementation of the 2003/30/EC Directive. Due to inconsistencies in official data, calculations were performed in order to determine actual consumption of agrofuels in France. This chapter also makes a critical assessment of the official presentation of agrofuels' environmental impacts in France and in the UK.

Chapter 6: *Conclusions and recommendations*

This last chapter summarizes key findings of this research and proposes recommendations to policy-makers on the way agrofuels' environmental impacts should be perceived. It also demonstrates that policy cannot do everything and that change in consumer behaviour is an important parameter to deal with, not only in terms of transport energy demand at the individual level but also in terms of dietary habits which greatly impact upon the amount of agricultural land needed.

Chapter 2:
What terminology to describe biomass-derived transport fuels?

"The difference between the right word and the almost right word is the difference between lightning and a lightning bug."
Mark Twain (1835-1910), American author and humorist

Introduction

In this thesis, the research will be focused on what are usually referred to as '1st-generation biofuels'. This common terminology encompasses the currently available transport liquid fuels made from biomass.

The hypothesis on which the research of this chapter is based is the following: "the wording used to promote biomass-derived transport fuels is neutral and does not lead to a polarization of the debate on their environmental impacts". Its utility is magnified when viewed against the larger thesis proposition as to the actual environmental 'sustainability' of biomass-derived transport fuels.

Transport liquid fuels made from biomass will be presented in the first instance. Then a neutral terminology relating to bioenergy is identified and presented: the FAO (Food and Agriculture Organization of the United Nations) United BioEnergy Terminology (UBET). Finally, wording used by proponents (especially the word 'biofuel' to describe current transport fuels made from biomass) and opponents of current biomass-derived fuels for transport are analyzed and critically evaluated.

Chapter objectives:

- Describe in detail current transport fuels derived from biomass;
- Critically analyse the use of the terminology 'biofuels' for liquid transport biomass-derived fuels as well as the use of other terminologies commonly used to refer to such fuels;
- Show why such terminologies are usually inappropriate and misleading;
- Justify the better adequacy of the terminology 'agrofuel' for the majority of current transport liquid biomass-derived fuels;
- Discuss the appropriateness of the terminology 'renewable' when referring to agrofuels as a source of energy.

2.1 Presentation of biomass-derived liquid transport fuels used in today vehicles

Transport fuels made from biomass are generally divided into '1st-generation' and '2nd-generation' 'biofuels' (and even sometimes '3rd-generation biofuels'). The IEA (International Energy Agency) Biomass Task 39 that works on 'Commercializing 1st- and 2nd-generation liquid biofuels from biomass' suggests the following classification (IEA Bioenergy: Task 39 'Commercializing 1st- and 2nd-Generation Liquid Biofuels from Biomass', 2008):

- "*First (1st)-generation biofuels are biofuels which are on the market in considerable amounts today. Typical 1st-generation biofuels are sugarcane ethanol, starch-based or ['maize'] ethanol, biodiesel and Pure Plant Oil (PPO). The feedstock for producing 1st-generation biofuels either consists of sugar, starch and oil bearing crops or animal fats that in most cases can also be used as food and feed or consists of food residues. A 1st-generation biofuel is characterized either by its ability to be blended with petroleum-based fuels, combusted in existing internal combustion engines, and distributed through existing infrastructure, or by the use in existing alternative vehicle technology like FFVs ("Flexible Fuel Vehicle") or natural gas vehicles. The production of 1st-generation biofuels is commercial today, with almost 50 billion litres produced annually. There are also other niche biofuels, such as biogas which have been derived by anaerobic treatment of manure and other biomass materials. However, the volumes of biogas used for transportation are relatively small today.*

- *Second (2nd)-generation biofuels are those biofuels produced from cellulose, hemicellulose or lignin. A 2nd-generation biofuel can either be blended with petroleum-based fuels, combusted in existing internal combustion engines, and distributed through existing infrastructure or is dedicated for the use in slightly adapted vehicles with internal combustion engines (e.g. vehicles for DME[1]). Examples of 2nd-generation biofuels are cellulosic ethanol and Fischer-Tropsch fuels. The production of 2nd-generation biofuels is non-commercial at the time of writing (2007), although pilot and demonstration facilities are being developed, [...].*
  Synthetic biofuels are 2nd-generation biofuels synthesized from gases made by thermal gasification of biomass, e.g.:
  - *Fischer-Tropsch fuels: Fuels for compression-ignition (=Diesel) engines or spark ignition ([petrol]) engines, also named BtL fuels ("Biomass to Liquid" fuels).*

[1] DME : Dimethyl Ether

- *SNG, synthetic natural gas produced by thermochemical processes.*
- *Dimethylether (DME), a gaseous fuel for compression-ignition engines.*"

This thesis concentrates on liquid 'biofuels', and therefore excludes biogas, SNG and DME, which are not fuels that are usable in current vehicle engines that run on petrol or diesel.

To sum up from above, current 'first-generation liquid biofuels' are mainly:

- ethanol from starch or sugar crops - usually called 'bioethanol' - (one can also add 'bio-ETBE' - Ethyl tert-butyl ether - that results from the reaction of 'bioethanol' with isobutylene) that is a substitute for petrol;
- fatty acid methyl esters (FAME) - usually called 'biodiesel' - from vegetable oil, waste vegetable oil and animal fat and also hydrotreated vegetable or animal oils (hydrogenated oils) that are substitutes for diesel.

'Second-generation liquid biofuels' consist of:

- ethanol from lignocellulosic biomass;
- synthetic fuels resulting from a Fischer-Tropsch reaction of gases obtained after thermal gasification of biomass.

Jatropha curcas L. (jatropha) is a plant sometimes hailed as a revolutionary biofuel feedstock because contrary to 1st-generation biofuel feedstocks, jatropha would not compete with food production (this idea is challenged in chapter 4) since its oil-rich fruits are not edible. Some jatropha proponents therefore claim that jatropha 'biodiesel' is a second-generation 'biofuel' (Air New Zealand, 2008; Cormack, 2008) but it seems that this characterisation is mainly for marketing purposes. Jatropha 'biodiesel' is made using the same technology as 1st-generation 'biodiesel': the transesterification of vegetable oil with methanol. Although jatropha is not very well known in agronomics (Achten *et al.*, 2008) its cultivation is not fundamentally different from that of other crops. Therefore, jatropha 'biodiesel' is a 1st-generation 'biodiesel'. This idea that jatropha 'biodiesel' is 1st-generation is found in a recent ActionAid report (Rice, 2010) as well as in a 2008 IEA report (Sims *et al.*, 2008).

Biodiesel from algae also attracted considerable attention as it does not require arable land and could potentially produce more oil per hectare than current oil crops (Sims *et al.*, 2008; Attia, 2009). However, growing algae for oil production is a new technology that might not be economically viable for several decades. It would also require sustainability assessments on top of life cycle assessments in order to determine whether it really brings environmental benefits.
Some distinguish algae biodiesel from other 'biodiesels' and call it a '3rd-generation biofuel' (European Algae Biomass Association, 2009) or 'advanced 2nd-generation biodiesel' (Sims *et*

al., 2008). However, apart from the feedstock production (which requires heavy research), 'biodiesel' production from algae oil relies on the same technology than 1st-generation biodiesel.

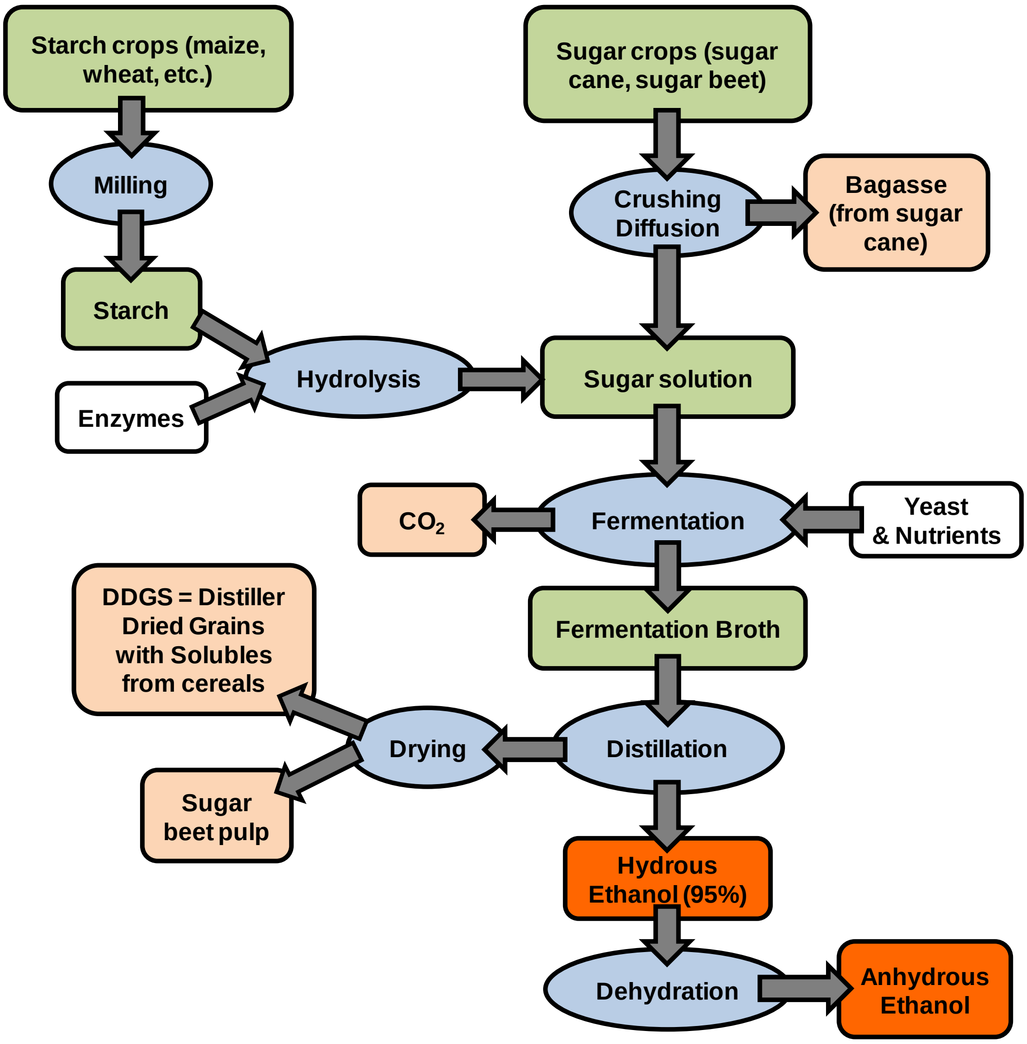
Before an appropriate and justifiable terminology is chosen to describe transport liquid fuels made from biomass, it seems important to have an overview of what feedstocks are needed and how final fuels are produced.

N.B.: In the four following flowcharts, successive feedstocks are in green rectangles, while processes are in blue ovals. Inputs entering the end fuel composition are within grey rectangles while those not entering the chemical composition of the end fuel are in white rectangles. Finally, by-products are in pink rectangles and end products (final fuels) in orange rectangles.

1[st]-generation biomass-based ethanol:

1[st]-generation ethanol from biomass comes from the ethanol fermentation of sugars in the presence of yeast. These sugars either come from sugar crops (such as sugar cane or sugar beet) or from starch-based plants like cereals (for instance maize and wheat) in which case starch firstly needs to be hydrolyzed into sugars. Ethanol obtained from the fermentation of sugars needs to be distilled to separate it from the fermentation broth, from which by-products such as sugar beet pulp or distiller dried grains with soluble (DDGS) can be produced after drying (such by-products are commonly used as animal feed). As some water vapour is also distilled during the distillation step, hydrous ethanol obtained after distillation is usually dehydrated to get anhydrous ethanol (cf. figure below). However, some recent studies suggest that hydrous ethanol could also be used in blends with petrol (Keuken *et al.*, 2008; Costa & Sodré, 2009), which would eliminate the need for the resource- and energy-intensive step of dehydration.

Figure 4: Simplified production flowchart of current biomass-based ethanol transport fuel



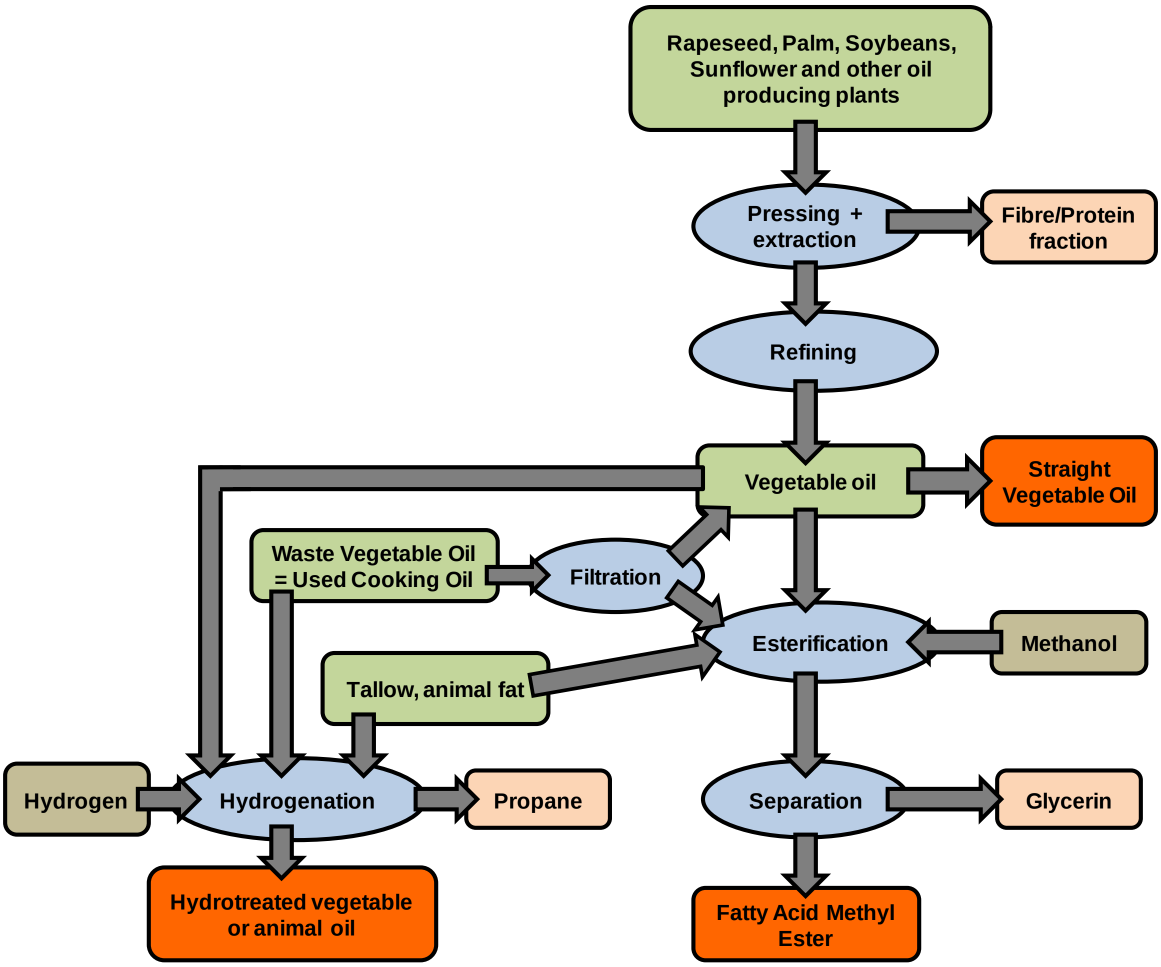
Source: Personal diagram partly inspired by CPL Press & European Biofuels Technology Platform (2009)

1st-generation biomass-based substitutes for diesel:

The production of 1st-generation biomass-based diesel substitutes relies on a very different technology. Fatty acids of any biomass origin (vegetable or animal fats, even used cooking oil) are filtered or refined and transesterified by reaction with methanol - usually of fossil origin - to form Fatty Acid Methyl Esters or FAME (biomass-derived ethanol is very rarely used, in which case Fatty Acid Ethyl Esters or FAEE are formed) which are often called ‘biodiesel’. On top of methyl (rarely ethyl) esters the transesterification reaction produces glycerin, which needs to be separated from the mix. However, pure plant oil or filtered used cooking oil can also be directly used and blended with fossil diesel in modified diesel engines (CPL Press & European Biofuels Technology Platform, 2009; European Commission, 2009a).

In the hydrogenated route, vegetable oils and animal fats are hydrogenated (reaction with hydrogen gas H_2) to produce a long carbon chain (called hydrotreated vegetable/animal oil) chemically similar to petrol diesel. Propane is a by-product of the hydrogenation reaction (cf. figure below).

Figure 5: Simplified production flowchart of current biomass-based substitutes to diesel

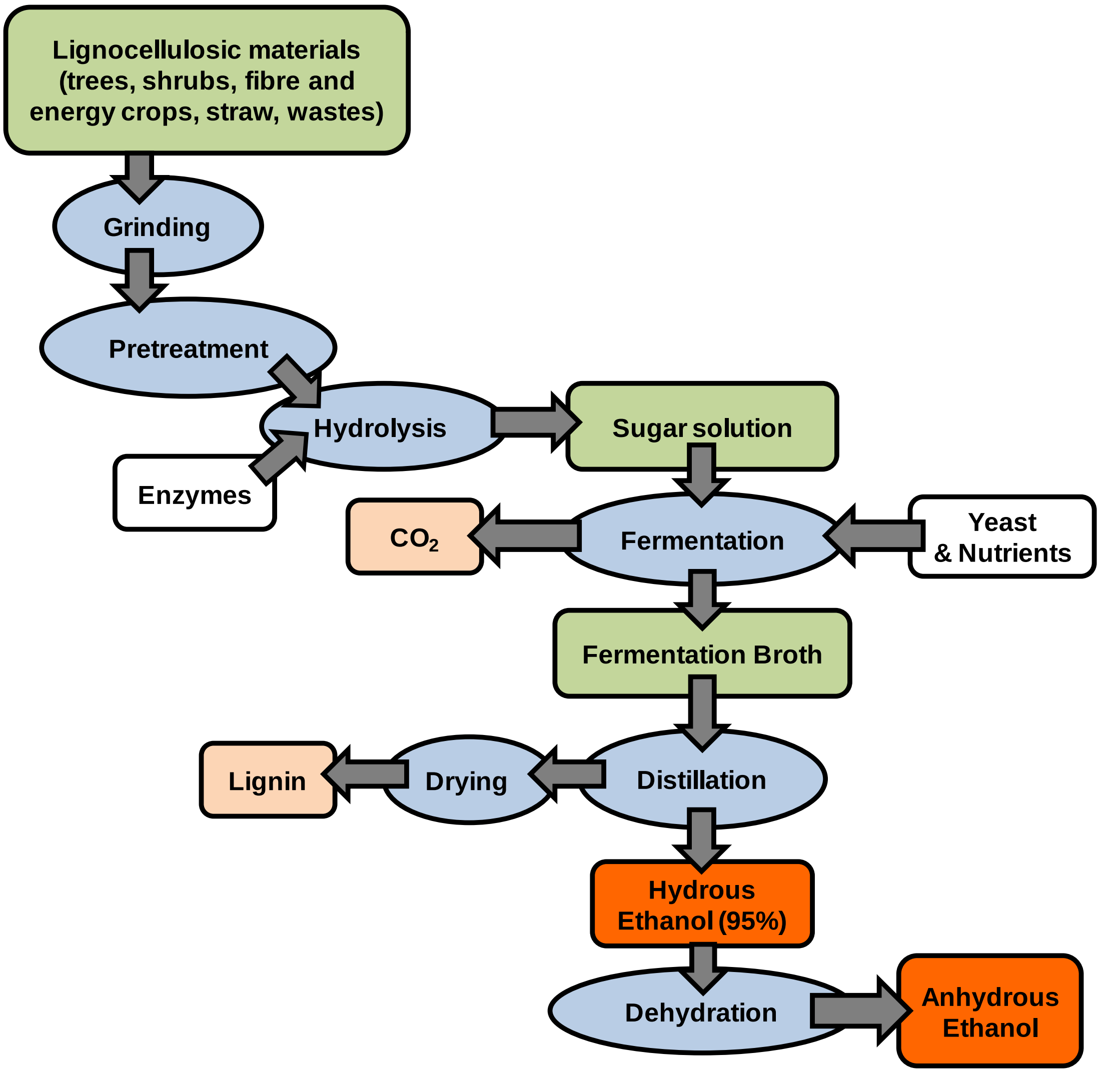


Source: Personal diagram partly inspired by CPL Press & European Biofuels Technology Platform (2009)

Lignocellulosic ethanol:

Lignocellulosic ethanol is produced after the ethanol fermentation of sugars obtained from the hydrolysis of lignocellulose. Lignocellulose is a very difficult molecule to break down, that is why a pretreatment of the lignocellulosic material is needed to separate lignin from cellulose and hemicellulose. Cellulose and hemicellulose are broken down by cellulase (an enzyme) and acids into sugars. Once sugars are formed, the process is similar to that of 1st-generation 'bioethanol'. This time the by-product is lignin (cf. figure below).

Figure 6: Simplified production flowchart of lignocellulosic ethanol

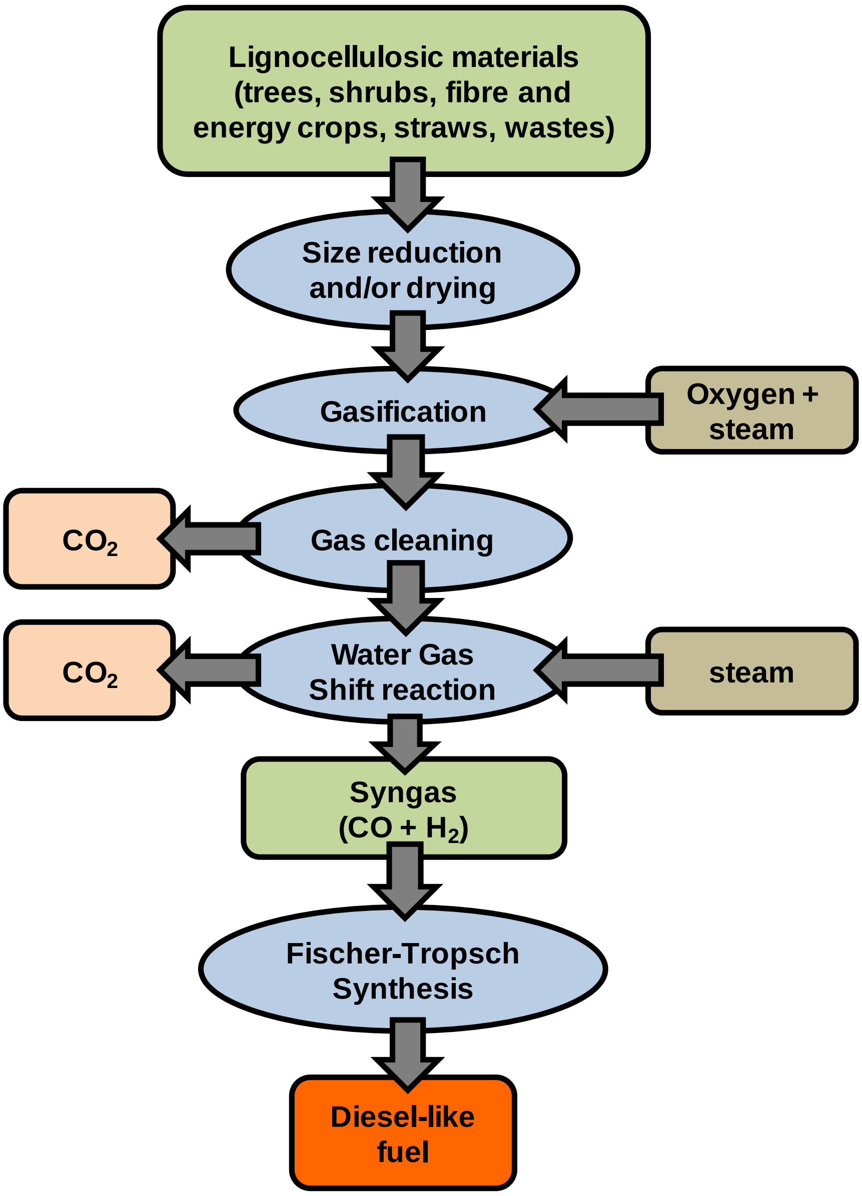


Source: Personal diagram partly inspired by CPL Press & European Biofuels Technology Platform (2009)

Biomass-derived Fischer-Tropsch substitute for diesel:

Finally, Fischer-Tropsch diesel is produced after a Fischer-Tropsch reaction on syngas (mix of carbon monoxide CO and hydrogen H_2). Syngas is obtained after a water gas shift reaction of the gases resulting from thermal gasification of lignocellulosic materials (cf. figure below).

Figure 7: Simplified production flowchart of synthetic biofuels



Source: Personal diagram partly inspired by CPL Press & European Biofuels Technology Platform (2009)

2.2 FAO UBET wording

As will be seen in section 3 of this chapter, the wording 'biofuel' is subject to controversy. However, it was thought that an insight of the FAO (Food and Agriculture Organization of the United Nations) Unified Bioenergy Terminology (UBET) could enable us to obtain a more neutral approach. According to the UBET, a ***biofuel*** is defined as a "fuel produced directly or indirectly from biomass", biomass being a "material of biological origin excluding material embedded in geological formations and transformed to fossil" (FAO Forestry Department, 2004). Biomass therefore excludes fossil fuels such as coal, petroleum or natural gas.

Contrary to the usual terminology of informal language, the UBET definition of 'biofuels' goes far beyond transport fuels derived from biomass and includes a large range of fuels made from biomass, from wood used for heating or cooking to bagasse (a sugar cane industry residue) burned for heat production in sugar mills.

According to the UBET, biofuels can be divided into three categories (cf. table below):
- *woodfuels*: fuels derived directly and indirectly from trees and shrubs;
- *agrofuels*: fuels obtained as a product of agriculture biomass and by-products at farming level, and/or industrial processing of raw materials (agro-industries);
- *municipal by-products* (fuels derived from municipal wastes).

Table 1: Classification of biofuels according to the FAO Unified BioEnergy Terminology

Production side	Common groups	User side, demand examples
Direct woodfuels Indirect woodfuels Recovered woodfuels Wood-derived fuels	WOODFUELS	**Solid**: fuelwood (wood in the rough, chips, sawdust, pellets), charcoal **Liquid**: black liquor, methanol, pyrolytic oil **Gases**: products from gasification and pyrolysis gases of above fuels
Fuel crops Agricultural by-products Animal by-products Agro-industrial by-products	AGROFUELS	**Solid**: straw, stalks, husks, bagasse, charcoal from the above biofuels **Liquid**: ethanol, raw vegetable oil, oil diester, methanol, pyrolytic oil from solid agrofuels **Gases**: biogas, producer gas, pyrolysis gases from agrofuels
Municipal by-products	MUNICIPAL BY-PRODUCTS	**Solid**: Municipal Solid Waste (MSW) **Liquid**: sewage sludge, pyrolytic oil from MSW **Gases**: landfill gas, sludge gas

Source: Adapted from FAO Forestry Department (2004)

It appears from the above table that ethanol, raw vegetable oil and oil diester (i.e. fatty acid ester) from energy crops, agriculture by-products, animal by-products and agro-industrial by-products are examples of 'agrofuels' according to the FAO UBET.

The UBET indeed defines agrofuels as "fuels obtained as a product of agriculture biomass and by-products at farming level, and/or industrial processing of raw material (agro-industries). The term covers mainly biomass materials derived directly from fuel crops and agricultural, agro-industrial and animal by-products".

Finally, the following table presents examples of fuel crops classified according to types of crops and types of farms.

Table 2 : Classification and examples of fuel crops

classification		description/example
land farms	sugar/starch crops	crops planted basically for the production of ethanol (ethyl alcohol) as a fuel mainly used in transport (on its own or blended with gasoline). Ethanol can be produced by the fermentation of glucose derived from sugar-bearing plants (like sugar-cane) or starchy materials after hydrolysis
	oil crops	oleaginous plants (e.g. sunflower, rape, etc.) planted for direct energy use of vegetable oil extracted, or as raw material for further conversion into a diesel substitute, using transesterification processes
	other energy crops	include plants and specialized crops more recently considered for energy use, such as: elephant grass (*Miscanthus*), cordgrass and galinggale (*Spartina* spp. and *Cyperus longus*), giant reed (*Arundo donax*) and reed canary grass (*Phalaris arundinacea)*
marine farms		algae
fresh water farms		water hyacinths

Source: (FAO Forestry Department, 2004)

Thus, 1st-generation liquid transport fuels from biomass could be described more precisely using the FAO UBET terminology:

- ethanol from sugar and starch crops is a *liquid agrofuel from fuel crops*;
- plant methyl esters and straight vegetable oil from oil-bearing plants are *liquid agrofuels from fuel crops*;
- methyl esters from tallow and animal fat are *liquid agrofuels from agro-industrial by-products* (from slaughterhouses);
- methyl esters of used cooking oil are *liquid municipal by-products from kitchen waste*.

Moreover, lignocellulosic ethanol and synthetic biomass fuels (often called '2nd-generation bioethanol') could be described more precisely according to their origin:

- if they come from wood and shrubs they are *liquid woodfuels*;

- from lignocellulosic energy crops they are *liquid agrofuels from energy crops*;
- from straw and fibres of agricultural crops they are *liquid agrofuels from agriculture by-products*;
- from lignocellulosic waste they are *liquid municipal by-products*.

This PhD concentrates on current liquid transport fuels made from biomass. Considering the above classification from the FAO, and putting aside methyl esters from used cooking oil (which is a marginal feedstock for 1st-generation liquid transport biomass fuels - less than 2% of 2008 world 'biodiesel' production according to data of F.O. Licht cited in $(S\&T)^2$ Consultants Inc. (2009b) - and is produced with the same technology than 1st-generation fatty acid methyl esters), these fuels should be specifically called 'transport liquid agrofuels' rather than the vague and unspecific term 'biofuels'. To avoid the use of a too complex wording and since this research focuses on liquid fuels for transport, the words 'liquid' and 'transport' are not thought to be necessary throughout this paper. This is why these fuels will be identified as '**agrofuels**' from this point.

Finally, to be consistent with this chosen wording and even though the following wordings are relatively uncommon, 1st-generation ethanol from energy crops will be from now called '**agroethanol**' and 1st-generation methyl esters from oleaginous plants and agro-industrial by-products (tallow and animal fat) will be called '**agrodiesel**'.

2.3 The wording used within the debate on agrofuels is problematic

The debate on agrofuels' terminology has been growing with the controversy on agrofuels' potential environmental impacts and benefits.

In this chapter, it is argued that the terminologies used by agrofuels proponents and opponents have fuelled a polarization of the debate, that lacks neutrality and objectivity.

2.3.1 Agrofuels proponents use misleading and inappropriate wordings

Apart from the wording issues that arise over the use of 'biofuels' (commonly used but too broad and therefore potentially misleading) and 'agrofuels' (more precise and neutral because it avoids a biology/natural connotation), agrofuel promoters have been known to refer to agrofuels in an unscientific light. They often use very positive terms such as the following qualifiers (illustrated with selected examples):

- *renewable* fuels. Agrofuels are assumed to be 'renewable fuels' for many organisations and laws dealing with agrofuels.

For instance, in the US the main national trade association for the ethanol industry[2] is called the RFA (*Renewable* Fuels Association) while the RFS (*Renewable* Fuel Standard) is a provision of the US Energy Policy Act of 2005 asking for more agrofuels to be consumed in the US (Office of Transportation and Air Quality, 2009).

In the UK, the RFA (*Renewable* Fuels Agency) is the organisation charged by the UK Government to run the RTFO (*Renewable* Transport Fuel Obligation) and allocate RTFCs (*Renewable* Transport Fuel Certificates) to agrofuel suppliers[3].

Finally, the European Commission (EC) has adopted two Directives that clearly suggest that agrofuels are considered as renewable. The 2003/30/EC Directive was entitled Directive 'on the promotion of the use of biofuels or other *renewable* fuels for transport' (European Commission, 2003), and the 2009/28/EC Directive 'on the promotion of the use of energy from *renewable* sources' (European Commission, 2009b) also deals with agrofuels and is commonly called RED for *Renewable* Energy Directive.

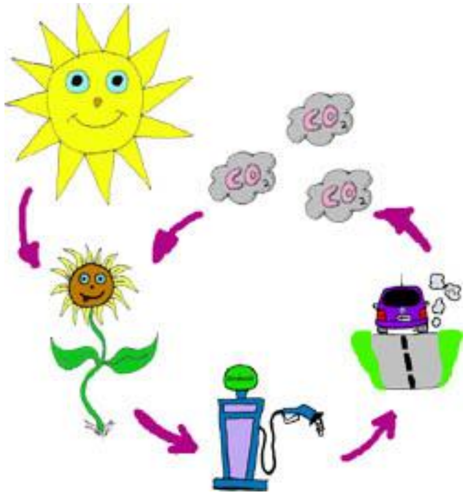
- *ecological* fuels. On its FAQ webpage about agrofuels the Spanish agrofuel producer Abengoa starts by saying that "biofuels are *ecological* fuels that replace the use of oil in transportation" (Abengoa Bioenergy, 2008).

- *environmentally friendly* fuels. According to Manning Feraci of the National Biodiesel Board (the national trade association representing the agrodiesel industry in the United States), "biodiesel is the most *sustainable*, *environmentally friendly* fuel available in the marketplace today (…)"[4]

- *carbon neutral* fuels. According to Sundays Energy, an American agrodiesel supplier, "Biodiesel is *Carbon Neutral* - Biodiesel has a Closed Carbon Cycle; therefore it does not Contribute to Global Climate Change". Below is the figure showing the '*neutral* CO_2 cycle of biodiesel' as seen on Sundays Energy webpage[5].

[2] Cf. http://www.ethanolrfa.org/about/philosophy/
[3] Cf. http://www.renewablefuelsagency.gov.uk/abouttherfa
[4] Cf. http://www.biodiesel.org/resources/pressreleases/gen/20090505_RFS2_Statement.pdf
[5] Cf. http://bdresource.com/index.php?option=com_content&task=view&id=284&Itemid=30

Figure 8 : The 'neutral CO_2 cycle of biodiesel' according to Sunday Energy



Source: http://bdresource.com/index.php?option=com_content&task=view&id=284&Itemid=30

Similarly, the website of the American car manufacturer Ford claimed in 2007 that "Flexifuel vehicles can be considered as truly *green* vehicles as they are part of a *'closed carbon cycle'* due to bio-ethanol having an almost *neutral* CO_2 balance" (Ford, 2007). Another video presentation of 2007 on the Swedish car manufacturer Saab' website similarly suggested that "[bioethanol] does not add extra carbon [into the atmosphere] since it is part of a closed eco-cycle" (Saab, 2007). In all these examples, agrofuels' place in the carbon cycle is oversimplified (in addition, the term 'eco-cycle' as used by Saab has no scientific meaning) and leads to a misleading presentation of agrofuels' GHG balance, implying that they are *carbon neutral* (or nearly *carbon neutral*).

- *low carbon* fuels. This designation appears in the Californian *Low Carbon* Fuel Standard (LCFS), a regulation calling for the reduction in the intensity of greenhouse gas emissions from California's transportation fuels by ten percent by 2020 (Farrell & Sperling, 2007a).

In the UK, the LowC^{VP} or *Low Carbon* Vehicle Partnership is "an action and advisory group, established in 2003 to take a lead in accelerating the shift to *low carbon* vehicles and fuels in the UK and to help ensure that UK business can benefit from that shift"[6]. Its motto is "accelerating the shift to *Low Carbon* Vehicles and Fuels" and its Fuel Working Group focuses on *low carbon* fuels "including biofuels and hydrogen".

- *clean* fuels. According to the *Clean* Fuels Development Coalition (CFDC), an American agrofuel lobby, "ethanol is a *clean* burning fuel that can have a significant impact on air quality (…) [and] that can dramatically reduce greenhouse gas emissions"[7].

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[6] Cf. http://www.lowcvp.org.uk/

[7] Cf. http://www.ethanolacrossamerica.net/

- *sustainable* fuels. The Roundtable on *Sustainable* Biofuels (RSB) describes itself as "an international initiative bringing together farmers, companies, non-governmental organisations, experts, governments, and inter-governmental agencies concerned with ensuring the sustainability of biofuels production and processing"[8]. The RSB developed a set of "principles and criteria for *sustainable* biofuels production" (Roundtable on Sustainable Biofuels, 2008) which suggests that agrofuels meeting such principles and criteria are *sustainable.*

In the UK, the *Renewable* Fuels Agency claims to be "the independent *sustainable* fuel regulator" on its webpage[9]. Moreover, the RFA claims it "will rigorously enforce the provisions of the RTFO (…) to ensure companies deliver upon their responsibilities to source *sustainable* biofuels" (RFA, 2009a), clearly assuming that compliance with the provisions of the RTFO enables one to get *sustainable* agrofuels.

- *green* fuels. '*Green* Fuels' is a very popular name for industries within the field of agrofuels. For instance, '*Green* Fuels' is the name of a British agrodiesel equipment supplier[10] as well as an Australian agrodiesel producer[11]. Louisiana *Green* Fuels is an American ethanol producer[12] and *greenfuels*.org is the webpage of the Canadian *Renewable* Fuels Association (which has the mission to promote the use of *renewable* fuels - namely 'ethanol and biodiesel')[13].

Finally, the qualifier '*2nd-generation*' used for ethanol from lignocellulosic sources and Fischer-Tropsch synthetic biomass-fuels is also a very positive term that implies such transport fuels are probably 'better' than current agrofuels. However, genetic modifications of lignocellulosic biomass feedstocks or enzymes that are needed to reduce the production cost of lignocellulosic ethanol raise concerns about potential release of GM (genetically modified) DNA in ecosystems while the overall environmental balance of such fuels is still uncertain (Ho, 2006b; Smolker *et al.*, 2008; Bringezu *et al.*, 2009; Global Justice Ecology Project, 2009).

The positive qualifiers illustrated above, though extremely common, are often not scientifically justified and present agrofuels in a manner that ignores uncertainties regarding their overall GHG emissions as well as their wider implications on the environment (this point will be developed in chapters 3 and 4).

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[8] Cf. http://rsb.epfl.ch/
[9] Cf. http://www.renewablefuelsagency.gov.uk/
[10] Cf. http://greenfuels.co.uk/
[11] Cf. http://www.greenfuels.com.au/
[12] Cf. http://www.lagreenfuels.com/who.html
[13] Cf. http://www.greenfuels.org/

This is why agrofuel proponents are regularly accused of ‘greenwashing’, which can be defined as “the misleading act of companies, industries, governments, organisations and individuals trying to promote unjustified environmentally friendly practices, products and services through branding, mislabelling, packaging or public relations”[14].

Part of the agrofuel sector belongs to industries that may be accused of using greenwashing arguments for the promotion of their products. Thus, several agrofuel producers were nominated “for their misleading campaigns to promote agrofuels as green” for the EU Worst Lobbying Awards 2008. Four other lobbies were competing for the award but in the end, the MPOC (the Malaysian Palm Oil Council), Unica (the Brazil Sugarcane Association) and Abengoa (Spanish multinational that also produces agroethanol) won the “Worst Lobbying Award 2008” with the vote of 52% of the 8,643 online voters.

Figure 9 : Caricature of the agrofuel lobby from the worslobby.eu website

Source: (worstlobby.eu, 2008)

Similarly an advertisement by ‘France Betteraves’ - the French association for the promotion of sugar beets - entitled ‘Some good news, at last!’ was forbidden by the French Regulation Authority on Advertisements after several NGOs pressed charges against it for greenwashing (cf. advertisement below).

[14] From http://www.azocleantech.com/Details.asp?ArticleID=109

Figure 10: Advertisement for sugar beet ethanol by France Betteraves withdrawn in 2009

Source: http://observatoiredelapublicite.fr/2009/02/01/france-betterave/

The advertisement was removed because of several misleading points[15]:
- the use of the green colour for the barrel shown next to a ladybird and butterflies (which infers the idea that sugar beets for ethanol production are produced according to organic farming practices or at least with low environmental impact agriculture);
- the claim that sugar beet ethanol would create thousands of jobs;
- the claim that this fuel is 30% less expensive at the pump;
- the claim that sugar beet is an inexhaustible source of renewable energy.

However, as seen earlier, agrofuel producers are not the only stakeholders that misleadingly present agrofuels as green. Some car manufacturers as well as some policy makers also use flawed terminology to promote agrofuels.

[15] Cf. http://www.jdp-pub.org/France-Betteraves.html

2.3.2 Agrofuels opponents react by using their own wording

The CEPA (Communication, Education and Public Awareness) toolkit seeks to provide guidance and help to biodiversity experts for their communication to the public (Hesselink *et al.*, 2007). Some of the main ideas developed in this toolkit are that “perception is the only reality” and that people have ‘conceptual frames’ in their mind “that help them sort incoming information quickly and to make sense of it” (p.37). Thus, according to the CEPA toolkit lead author Frits Hesselink, “if we talk about bio-fuels, our mind immediately associates bio with positive connotations such as biological, environment friendly etc. And we do not want to listen anymore to negative connotations. Agro is associated with large scale industrial production and intensive land use etc. That makes it much easier to talk about for e.g. land taken away from local food production etc.” [16]

Indeed as a reaction to the mainstream terminology ‘biofuels’ many environmental Non-Governmental Organizations (NGOs) but also individuals that are dubious on agrofuels environmental benefits seem to prefer the word ‘agrofuel’ than the word ‘biofuel’.

For instance, Friends of the Earth (FOE) uses the word ‘agrofuels’ when agrofuel feedstocks “are grown in intensive agricultural systems, such as environmentally-damaging large-scale monoculture plantations” (Friends of the Earth, 2008) while a leaflet from the Global Forest Coalition (Global Forest Coalition & Global Justice Ecology Project, 2007) uses the word ‘agrofuel’ to highlight the fact that agricultural crops or lands are taken over to produce agrofuels. Finally, a GRAIN report (GRAIN, 2007) states that “the prefix bio, which comes from the Greek word for “life”, is entirely inappropriate for such anti-life devastation [and that] agrofuels is a much better term […] to express what is really happening: agribusiness producing fuel from plants to sustain a wasteful, destructive and unjust global economy”.

Tad W. Patzek - professor of geoengineering at the University of California, Berkeley, and prominent agrofuels sceptic - is cited in a 2008 Nature report saying that “people are beginning to see that the damage ensuing from producing agrofuels by far outweighs any possible benefits” (Kleiner, 2008).

In a report by the Institute for Food and Development Policy the author distinguishes “local production for cooking and other energy needs ([which he] call[s] *biofuels*), as opposed to [agrofuels] displacing food production and food security to ship the finite agricultural resources of the Global South out of region and around the globe” (Jonasse, 2009).

[16] Cf. http://cepatoolkit.blogspot.com/2007/06/not-bio-fuels-agro-fuels.html

In a white paper of 2009, the Rainforest Action Network defines agrofuels as “fuels made through an industrialized process from dedicated agro-crops or from biomass-based feedstock” and opposes them to biodiesel made from recovered waste vegetable cooking oils in local non-industrialized processes (Rainforest Action Network, 2009).

The word ‘agrofuel’ is thus often preferred to ‘biofuel’ by critics to designate current transport liquid fuels made from agriculture crops (Gilbertson *et al.*, 2007; Lang, 2008; Global Justice Ecology Project, 2009). However, some other wordings are used to refer to agrofuels by their critics.

A 2010 report by ActionAid (Rice, 2010) presents what types of fuels deserve to be called biofuels (which once again includes recycled vegetable oil) but chooses the wording ‘industrial biofuels’ to refer to large-scale agrofuels:

> “*biofuel is fuel obtained from biological material. But the term ‘bio’ also implies some sort of environmental benefit (for example the French word for organic is biologique) and the term has been hijacked by the biofuels industry to portray a green image. The term biofuel, by itself, should only refer to fuel produced from waste processes such as landfill off-gassing, recycled vegetable oil or small scale sustainable production for local use. Agrofuels are also biofuels but refer to the fact that the biological material is an agricultural crop, produced intensively by agribusiness, in large-scale monoculture plantations and which competes, directly or indirectly, with food. These are agrofuels produced on an industrial scale. The term ‘***industrial biofuel***’ rather than agrofuel is used in this report.”*

The following scholars - that are critical about agrofuels - use the wording ‘agro-biofuel’ for 1st-generation transport liquid fuels made from biomass:
- Crutzen *et al.* in the 2007 article on N_2O emissions from agrofuels (Crutzen *et al.*, 2008)
- Giampietro and Mayumi in the 2009 book “The biofuel delusion – The fallacy of large-scale agro-biofuel production” (Giampietro & Mayumi, 2009)

Finally, Fabrice Nicolino – who wrote a book opposing agrofuels’ development (Nicolino, 2007) - is known in France for using the word ‘*nécrocarburant*’ (‘necro’ meaning ‘death’ in ancient Greek as opposed to ‘bio’ meaning ‘life’) - which could be translated in English as ‘necrofuel’ - to denounce the fact that according to him, current agrofuels expand thanks to deforestation, the massive use of pesticides and fertilizers and are used as a “weapon of war and death”[17].

[17] Cf. http://www.novethic.fr/novethic/planete/environnement/energie/l_expansion_necrocarburants/111684.jsp

2.3.3 Main confusions raised from the use of the word 'biofuel'

2.3.3.1 Confusion with organic farming in several European languages

The word 'biofuel' is a portmanteau of 'biomass' and 'fuel'. Its equivalent was created in many languages in a similar way than in English and also commonly refers to 'transport fuel from biomass' although 'transport liquid agrofuels' is more specific and appropriate for today biomass transport fuels.

Thus, 'biofuel' is said: '**bio**carburant' in French, '**bio**carburante' in Spanish, '**bio**combustibile' in Italian, '**Bio**kraftstoff' in German.

But in these languages, organic farming is said: 'agriculture **bio**logique' in French, 'agricultura ecológica' or 'agricultura **bio**lógica' in Spanish, 'agricoltura **bio**logica' in Italian, 'ökologische Landwirtschaft' or '**bio**logische Landwirtschaft' in German (cf. following figure for some logos of organic farming certification). Moreover, in French, Italian and German, '**bio**' is the word commonly used in daily language to refer to organic products.

Figure 11: French and German logos of Organic Farming certification

Since the prefix '**bio-**' refers to the translation of 'organic' in other languages, confusion can arise among consumers in continental Europe, who may sometimes believe that 'biofuels' are fuels made from crops produced according to organic farming practices. Such confusion cannot happen when the wording 'agrofuel' is used.

During a personal conversation in October 2007, Angela Caudle de Freitas, Executive Director at the time of the IFOAM (International Federation of Organic Agriculture Movements) said that to her there was a fundamental incompatibility between so-called 'biofuels' and the ideals behind organic farming. Nevertheless, it seems that some organic farming centres are looking for ways to reduce their reliance on fossil fuels and thus experiment ways to produce biomass with low environmental impact to fuel their machinery (Fredriksson *et al.*, 2006; ICROFS, 2008; Muller, 2009).

Olivier Danielo, a French environmentalist suggests on his blog that he introduced the terminology ‘agrocarburant’ in a 2004 *Ouest-France* article because he was worried by the confusion with ‘agriculture biologique’ (Danielo, 2009). According to him the terminology ‘agrocarburant’ is now mainstream (it is regularly used in major newspapers such as *Le Monde* and *Le Figaro* as well as by the French Ministry of the Environment). Indeed a ‘Google Fight’ performed on 20th February 2010 gives 119,000 finds for ‘biocarburants’ and ’39,800’ for ‘agrocarburant’. This ratio of about 3:1 shows that ‘agrocarburant’ has become a common denomination for transport biomass fuels in French.

In a 2009 debate on French public channel *Public-Sénat*, Claude Saunier - a former French senator - stated that he preferred the wording ‘agrocarburant’ than ‘biocarburant’ because unlike organic farming (‘*agriculture biologique’*), agrofuel production requires very industrialised and intensive practices. A member of the sugar beet ethanol industry replied that the wording ‘biofuels’ had been specifically defined by European Directives, which justifies according to him that this wording is kept in the common language. His point was agreed wholeheartedly by Ghislain Gosse - a French scientist from INRA (*Institut National de la Recherche Agronomique* - French National Institute for Agricultural Research) - who claimed that the discussion of the wording ‘biocarburant/agrocarburant’ was a ‘Franco-French’ debate, and that “English speakers did not soul-search on this issue and were perfectly right not to” (Duquesne, 2009). However, as seen earlier, the debate on wording also exists in English-speaking countries (even though the wording ‘agrofuel’ is mainly used by critics only) and a main difference is that the confusion with organic farming is not possible in English because of the difference in wording. Moreover, the terminology using the prefix ‘agro-’ rather than ‘bio-’ is also used by critics in Spanish, German and Italian (‘agrocarburante’, ‘agrocombustibile’ and ‘Agrokraftstoff’). Thus the debate on wording goes beyond French borders.

Incidentally, the French Senate saw intense discussions in July 2009 regarding the wording for liquid biomass transport fuels[18]. It was firstly generally agreed that the word ‘biocarburant’ should be replaced by the more neutral term ‘agrocarburant’ when referring to 1st-generation transport liquid fuels from agriculture biomass. Some also recommended that commonly called 2nd-generation fuels made from forestry biomass be called ‘sylvocarburants’ (‘silva’ meaning ‘forest’ in Latin), which would be ‘silvofuels’ in English. Transport biomass fuels as a whole would keep the wording ‘biocarburant’ but among them the different types of fuels would get a more precise terminology according to their feedstock. However, these agreements on terminology were eventually rejected a few days after the initial discussions even though they

[18] Cf. http://www.senat.fr/basile/visio.do?id=s20090701_13&idtable=s20090701_13|s20081203_19|s20090130_15&_c=agrocarburant&rch=gs&de=20081116&au=20091116&dp=1+an&radio=dp&aff=sep&tri=p&off=0&afd=ppr&afd=ppl&afd=pjl&afd=cvn&isFirst=true

had been supported by the secretary of state for the environment[19]. Nevertheless, the term 'agrocarburants' is now being used in French on a regular basis and not only by critics.

Finally, it is interesting to note that the words 'petrofuel' and 'petrodiesel' are sometimes used to refer to fossil fuels and fossil diesel, which stresses the difference between biomass fuels and fossil transport fuels. 'Petro-' is actually a prefix meaning 'rock' in ancient Greek (petroleum literally means 'rock oil'). Moreover, whereas the concept of 'well-to-wheel' is used in the oil industry to present all environmental impacts of oil along its lifecycle, the wording 'farm-to-forecourt' is sometimes used when mentioning the lifecycle impacts of agrofuels. Such a terminology simplifies the life of an agrofuel in a way that the only impacts that come to our mind are reduced to those associated with the cultivation of the feedstock. However, numerous chemical products are needed all along the chain and require considerable amount of matter as well as energy for their production (for instance fertilisers). The term 'cradle-to-grave 'or simply 'lifecycle' is thus thought more appropriate and less subjective to refer to agrofuels' associated impacts on a lifecycle basis.

2.3.3.2 Some 'biofuels' are not entirely made up of biomass

Another point of confusion comes from the fact that despite the prefix 'bio-', some 'biofuels' are not entirely made of biomass (or despite the prefix 'agro-', some 'agrofuels' are not entirely made of agriculture biomass).

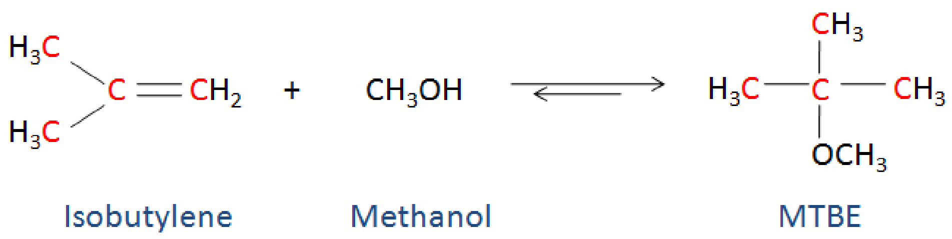
Thus, in its 2003/30/EC 'Biofuel Directive', the European Commission (EC) listed among what it considers as biofuels:

- "'bio-ETBE (ethyl-tertio-butyl-ether)': ETBE produced on the basis of bioethanol (the percentage by volume of 'bio-ETBE' calculated as biofuel is 47%);
- 'bio-MTBE (methyl-tertio-butyl-ether)': a fuel produced on the basis of biomethanol (the percentage by volume of 'bio-MTBE' calculated as biofuel is 36%)".

'Bio-ETBE' and 'bio-MTBE', though listed as 'biofuels' and therefore carrying the prefix 'bio' are only partially counted as 'biofuels' because 'bio-ETBE' and 'bio-MTBE' come from the reaction between fossil isobutylene (a common by-product from oil refineries) and agroethanol or agromethanol. In the following figures, carbon atoms of fossil origin (from the molecule of isobutylene) are marked in red so that they can be identified in the final molecules of MTBE and ETBE.

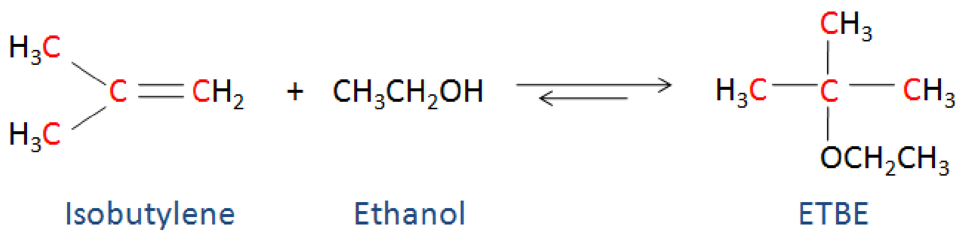
[19] Cf. http://s225161339.onlinehome.fr/wordpress/2009/07/03/loi-grenelle-1-deuxieme-lecture-au-senat-agrocarburants-biocarburants-marche-arriereles-absents-votent/

Figure 12: Chemical reaction between isobutylene and methanol to produce MTBE



Source: Personal chemical drawing

Figure 13: Chemical reaction between isobutylene and ethanol to produce ETBE

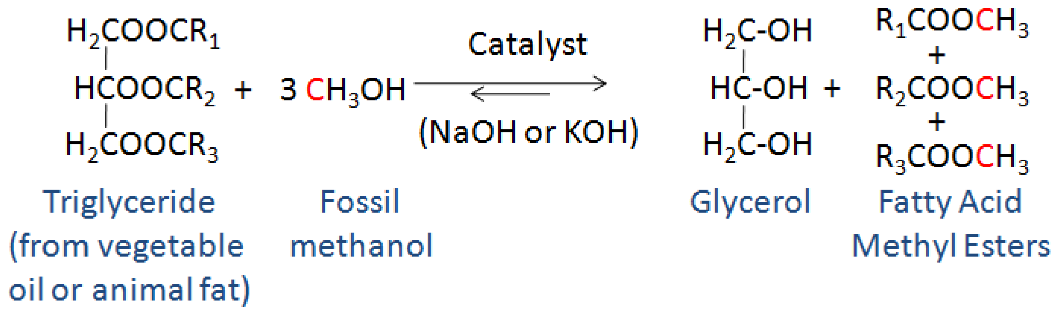


Source: Personal chemical drawing

Chemically speaking, more than half of the molecules of 'bio-ETBE' and 'bio-MTBE' have a fossil origin (64% by volume for MTBE and 53% by volume for ETBE according to the 2003/30/EC Directive). This raises a question as to the appropriateness of the 'bio-' prefix. To be more consistent with our chosen terminology, such fuels will be called '**agro-ETBE**' and '**agro-MTBE**', but one needs to keep in mind that only a fraction of these fuels comes from biomass.

It is interesting to note that agrodiesel - which is a mix of Fatty Acid Methyl Esters (FAME) - comes from the transesterification of a fatty acid (from vegetable oil or animal fat) with methanol which has usually been synthesized from (fossil) natural gas. Therefore, similarly to agro-ETBE and agro-MTBE, not all the atoms of agrodiesel molecules are of biomass origin (cf. figure below).

Figure 14: Chemical reaction between a triglyceride and methanol to produce agrodiesel



Source: Personal chemical drawing

In the above figure, R_1, R_2 and R_3 are long carbon chains (alkyl groups) that depend on the feedstock. Carbon atoms of fossil origin (from the molecule of methanol) are marked in red so that they can be identified in the final molecules of FAME. In this case, a methyl (CH_3) group is of fossil origin in each agrodiesel molecule.

According to Elsayed *et al.* (2003), 109 kg of methanol is consumed for the production of 1 tonne of oilseed rape methyl ester. This means that about 109/1000=11% of the weight of agrodiesel is of fossil origin. However, despite the fact that not all atoms of 'biodiesel' come from biomass, the 2003/30/EC Directive does not require that only the biomass fraction of biodiesel is counted as 'biofuel'.

On the contrary, the UK OFGEM (Office for Gas and Electricity Markets) decided in 2009 not to allow agrodiesel produced with the use of fossil methanol (from natural gas) to claim ROCs (Renewable Obligation Certificates) because a part of the molecule of agrodiesel is of fossil origin (OFGEM, 2009).

One can notice that 'biofuels' of the 2003/30/EC list that have a name starting with 'bio' are only the fuels that require an industrial process (and among them 'biofuels' that are not entirely made from biomass such as 'bio-ETBE', 'bio-MTBE' and 'biodiesel'). Although 'pure vegetable oil' is the most directly available 'biofuel' in the 2003/30/EC list, needing only very basic technologies for its production (vegetable oil from crushed oilseeds just needs to be purified before it can be used as a 'biofuel'), ironically, it is the only 'biofuel' of the list not to have a name starting with 'bio'.

Finally, it is interesting to note that the European Directive 2009/28/EC introduces the word 'bioliquid' that means "liquid fuel for energy purposes other than for transport, including electricity and heating and cooling, produced from biomass" (European Commission, 2009a). Thus, agrodiesel used for electricity generation is a 'bioliquid' according to the European Commission whereas it would be considered as a 'biofuel' if it was used for transport. Such distinction of wording linked to end use is not found in the UBET but seems to once again rely on the attractiveness of the prefix 'bio-'.

2.3.4 Are agrofuels renewable sources of energy?

Although very commonly used, the term 'renewable energy' has today no definitive definition. According to Gritsevskyi (2008), many definitions of 'renewable energy' are problematic, including the ones given by some United Nations (UN) manuals. Most definitions just give a listing of what are supposed to be renewable energies (usually solar, hydro, wind, geothermal, wave and tidal, biomass, etc.). Hoexter tried to give a more rigorous definition and describes renewable energy sources as practically inexhaustible "useful natural energy stores that are replenished by natural flux within the timeframe of conceivable human use" (Hoexter, 2007). However, the last part of the sentence allows for some subjectivity as most energy sources are replenished by natural fluxes (even so-called fossil fuels). For instance, the age of coal reserves ranges between 20 and 325 million years and the Earth's crust still forms coal. But coal is said to be non-renewable because its renewability rate is so small that it is irrelevant for society (Joosten, 2004). On the other hand, living wood has an age ranging from 3 to 100 years usually (but up to 5,000 years). The following question lies outside the scope of this thesis but one can wonder whether old trees would qualify as a source of renewable energy.

Now, permit us to observe that renewable energies are not necessarily benign to the environment. An IEA report from 1998 though very positive about renewable energies acknowledged that the harnessing of renewable sources of energy could also have serious environmental implications (IEA, 1998). Thus, large dams have been significantly criticised not only for disrupting aquatic ecosystems, but also for causing the emission of large quantities of methane - a very potent greenhouse gas - from the anaerobic decay of flooded plant material (Graham-Rowe, 2005). The International Rivers Network even launched a campaign in 2003 against large hydro (IRN, 2003), asking for them to be excluded from renewables initiatives.

Figure 15: Logo of the "Renewables YES! Big Hydro No!" declaration

Source: http://www.internationalrivers.org/files/images/renewables.gif

According to the UBET definition (FAO Forestry Department, 2004), a renewable energy "consists of energy produced and/or derived from sources infinitely renovated (hydro, solar, wind) or generated by combustible renewables (*sustainably produced biomass*)".

This definition implies that renewable biofuels (in the general sense of biomass used for the production of bioenergy) must come from sustainably produced biomass. This also implies that not all biomass is sustainably produced and that energy from unsustainably sourced biomass cannot be said to be renewable. Indeed, the heat produced from the combustion of wood coming from a cut-down forest that is not replanted (therefore the energy store is not replenished) cannot be said to be renewable. Within the UBET definition of renewable energies, 'sustainably produced biomass' probably means that the biomass that is used to produce energy is replenished (trees grow again at the place of the cut-off trees, the fuel crop is re-cultivated, etc.).

However, according to the Global Justice Ecology Project (2009), "while plants do re-grow, the soils, nutrients, minerals and water they require are in limited supply". This sentence infers that biomass produced in a non-cyclic way (when feedstock residues are not used as soil amendments) and that remove too much water from a water-scarce area cannot be said to be renewable.

Finally, agrofuels' production – or the harnessing of biomass for agrofuel production - involves numerous steps such as land use, cultivation, harvest, industrial processes, etc. (cf. chapter 3) that deplete carbon stores or that are currently commonly based on the use of non-renewable energy sources. With these impacts in mind, it becomes difficult to claim that today agrofuels are renewable.

N.B.: According to the Directive 2009/28/EC (p. 27), " 'energy from renewable sources' means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases; (…) [and] 'biomass' means the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste" (European Commission, 2009a). According to this Directive and contrary to the UBET definition, any biomass is considered to be renewable. However, the European Directive further introduces what are called 'sustainability criteria' for 'biofuels and bioliquids' (which will be discussed in chapter 4).

The ambiguous phrase 'sustainably produced biomass', which is the condition for the renewability of biomass according to the UBET definition may also refer to the notions of 'sustainability' and 'sustainable development'. However, there is no widely accepted definition of 'sustainable development'.

The 'Bruntland Report' (World Commission on Environment and Development, 1987) defined 'sustainable development' as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". However, it is difficult to assess what are present real needs and one cannot know what future generations' needs will be. What is more, the Bruntland report clearly believed that economic growth (even in industrial countries) was a key to 'sustainable development'. The three components of 'sustainable development' were reaffirmed in a 2005 UN document to be "economic development [understand 'economic growth'], social development [or social equity] and environmental protection" (General Assembly of the United Nations, 2005). But the idea that economic growth is compatible with a development that is truly sustainable is being increasingly challenged (Jackson, 2009) and the terminology 'sustainable development' is increasingly presented as an oxymoron. Bertrand Méheust wrote in a 2009 book that the more oxymorons are used (such as 'sustainable development' and 'moralisation of capitalism' for instance) the more people are bewildered and inapt to think (Méheust, 2009), which shows the importance of terminology and related claims of the kind that have been analysed herein.

Conclusion

In this chapter it was shown that the terminology used for agrofuel promotion was often misleading and that the word 'biofuel' commonly used to refer to current transport liquid biomass fuels was not as appropriate as the word 'agrofuel' that will be kept for the following of this thesis. While most agrofuel critics prefer the word 'agrofuel' to show their disapproval of this technology they are actually using the FAO UBET recommended wording. Thus, there is no need to justify this change of prefix by claiming that today agrofuels are produced by agro-business or to stress the fact that agrofuel production removes crops from food production. However, the word 'biofuel', though still more commonly used, is clearly inappropriate in that it refers to any source of bioenergy according to the FAO UBET and also introduces confusion with organic farming practices in several European languages. It was also shown that agrofuels are not all entirely made of biomass. Whereas it is recognised for agro-ETBE and agro-MTBE, the EC does not acknowledge the fact that agrodiesel is not 100% biomass-made. Finally, agrofuel renewability may be questioned because sustainable production of agrofuel may be unachievable.

The next chapter will focus upon analysing and understanding the environmental implications of agrofuels.

Chapter 3:
Agrofuels' environmental impacts are numerous and poorly understood

"As for me, all that I know is that I know nothing."
Socrates (469 BC–399 BC), philosopher of Ancient Greece

"We don't know a millionth of one percent about anything."
Thomas Edison (1847-1931), American inventor

Introduction

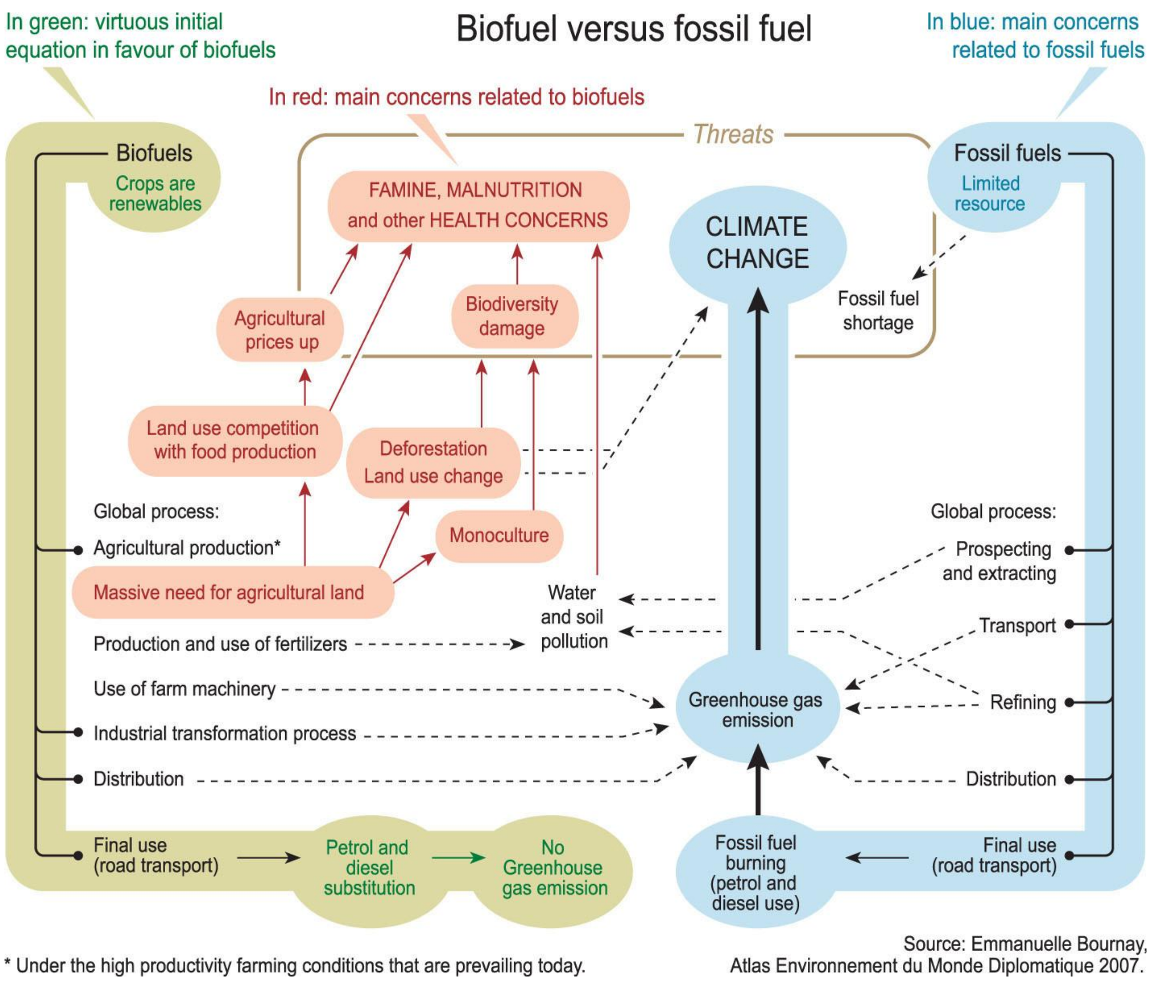
As seen in chapter 2, agrofuels are often promoted for their expected GHG benefits compared to petrol and diesel. However, there are fears that agrofuels have a higher environmental cost than the potential benefit they seem to bring at first sight.

The hypothesis that this chapter aims to test is the following: "Agrofuels' adverse environmental implications are scarce and well understood. Moreover, greenhouse gas lifecycle assessments encompass all GHG emissions associated with agrofuels."

Agrofuels' environmental and social impacts have been subject to harsh controversy since several years and have thus been widely debated even in the mainstream media (Monbiot, 2005b; Pearce, 2005; Brown, 2006; Farrow, 2007; Permatasari & Lo, 2007; Phillips, 2007; Rosenthal, 2007; Radio Canada, 2008).
The controversies relate not only to agrofuels' overall environmental impacts associated with their development, such as adverse effects on biodiversity, soils, water, etc. but also to their GHG emissions – even though agrofuels' expected GHG emission reduction is one of the main arguments for their promotion.

Since agrofuels come from agriculture biomass and are used as transport fuels, they have by nature a large spectrum of potential environmental impacts.
The following figure presents a summary of the main areas of concern of agrofuels compared with those of fossil fuels. All these issues will be largely developed in this chapter.

Figure 16: Agrofuels versus fossil fuels



Source: (Bournay & UNEP/GRID-Arendal, 2007)

In the first section of this chapter, agrofuels' direct environmental impacts along their lifecycle will be listed with a particular focus on direct GHG emissions while in a second instance, indirect impacts associated with agrofuels will be assessed and exemplified.

<u>Chapter objectives</u>:

- Identify the complexity of the attribution of environmental impacts of agrofuel chains to agrofuels specifically;
- Present a largely exhaustive list of direct environmental impacts associated with agrofuels' production and some uncertainties related to their understanding;
- Show the multiplicity of sources of direct GHG emissions along agrofuel chains and the difficulty of GHG counting;
- Provide a general definition of indirect land-use change (iLUC) and present the complexity of this notion;
- Identify some indirect impacts of agrofuels that are not necessarily linked with iLUC.

3.1 Agrofuels' potential direct negative environmental impacts

In this section, a largely comprehensive listing of agrofuels' direct environmental impacts is developed as it was thought important to have a comprehensive overview of the direct consequences of agrofuels' production on the environment. For the purpose of this thesis, there will be a more particular focus on GHG emissions related to agrofuels' development. Unless it is stated, in this section, agrofuels considered are the most important ones today: agrodiesel and pure vegetable oil from oil crops, agroethanol from sugar and starch crops and ETBE from agroethanol.

Agrofuels' production is equivalent to harnessing solar energy in the form of photosynthesised carbon from agriculture biomass and making it available as automotive power. However this process of harnessing a resource that is potentially renewable is not itself necessary environmentally benign.

Agrofuels' potential direct adverse environmental impacts are very diverse because:

- agrofuels are produced from agriculture feedstocks. Environmental impacts coming from the agriculture step of their production can affect all environment aspects: soil, water, air, biodiversity, etc.;
- agrofuel agriculture feedstocks are usually industrially processed for agrofuel production (transesterification of vegetable oil for agrodiesel and distillation of sugary broth for agroethanol);
- agrofuels are blended with fossil fuels and combusted in internal combustion engines (ICE) of cars;
- agrofuels are a land-intensive source of energy and thus require a considerable amount of land, which induces indirect impacts (cf. section 2 of this chapter).

3.1.1 Potential environmental impacts from the end product

The most directly visible potential impacts of agrofuels are the impacts of the physical agrofuel itself whether it is agroethanol or agrodiesel.

3.1.1.1 Agrofuels' toxicity

Like any chemical, agrofuels can be toxic to humans and to ecosystems above certain levels of concentration. However, agrofuel toxicity is not always very well known in terms of human health (during air or water exposure).

- Straight vegetable oil (SVO), which can be used as a transport fuel is often used for cooking and eaten raw for instance in salad dressings (when edible). Even if it is only very slightly toxic, SVO spills at sea would have adverse impacts on ecosystems such as the oiling of the coastline and birds as well as the reduction of oxygen dissolved in water during SVO biodegradation (Cedre, 2004).

- Agrodiesel and agrodiesel blends are less toxic than conventional diesel (however, agrodiesel is not edible) but their risk to aquatic ecosystems is still substantial according to Khan *et al.* (2007a). Therefore they should be "handled with care to avoid contamination of the watersheds".

- As for ethanol, it is the molecule that is called 'alcohol' in alcoholic drinks. Ethanol is an addictive molecule that is with caffeine the most widely used drug substance in the world (US National Library of Medicine, 2009). Once again, ethanol spills are not as damaging to ecosystems as petrol spills but high concentrations of ethanol in streams can kill aquatic fauna (Owen, 2009).

- Agro-MTBE (called 'bio-MTBE' in the 2003/30/EC Directive) is chemically identical to MTBE synthesised in oil refineries and used as a fuel additive aimed at improving air quality. However, it has been banned in many states of the US[20] because it seems to pose high risks to aquatic ecosystems and is a persistent pollutant (Davis & Farland, 2001). Moreover, it gives an unpleasant taste to drinking water at very low concentrations. Agro-ETBE seems to have a smaller effect on health in the short-term (de Peyster *et al.*, 2009).

3.1.1.2 Agrofuels' tailpipe emissions

Transport liquid fuels react with oxygen (O_2) from the air in internal combustion engines (ICE) of vehicles. The heat released during fuel combustion is then partly converted into mechanical energy that makes the vehicle move forward.

Theoretically, fossil fuels are pure hydrocarbons that should be entirely burnt into carbon dioxide CO_2 and water H_2O. But fossil fuels are not entirely clean (they contain e.g. some sulphur and trace metals) and they react not only with O_2 (dioxygen) from the air but also with N_2 (dinitrogen) which is the dominant gas in the atmosphere. What is more, the combustion is not complete because the conditions are not perfect for the reagents to react totally together in

[20] http://www.eia.doe.gov/oiaf/servicerpt/mtbeban/table1.html

an ICE. Finally, the quality of the combustion is highly dependent on the specific engine (therefore the vehicle that is examined) and the eventual use of a catalytic converter.

One positive aspect of agrofuels regarding tailpipe emissions is that contrary to fossil fuels, agrofuels contain oxygen atoms, which ease combustion. What is more, they do not contain sulphur which would otherwise be oxidised into sulphur oxides (SO_x) that can cause respiratory diseases (Rutz & Janssen, 2007).

Main tailpipe emissions of cars consist in CO_2 and water vapour emissions. Tailpipe emissions (also called Tank-to-Wheel - TTW - emissions) are measured in weight per unit of energy input (g/MJ) or per km covered (g/km).

Researches show that tailpipe emissions of GHG (CO_2, CH_4 and nitrous oxide N_2O – water vapour is generally not included in GHG emission calculation because it has a very small residence time in the atmosphere) are pretty much the same between fossil fuels and agrofuels. Actually, ethanol TTW GHG emissions are 4% lower than petrol TTW GHG emissions whereas agrodiesel TTW GHG emissions are 3.5% higher than TTW GHG emissions of fossil diesel (Edwards *et al.*, 2007c).

However, tailpipe emissions of several pollutants can be very different between fossil fuels and agrofuels.

Urban areas have been suffering for decades of poor air quality with tailpipe emissions from cars accounting for a large part of air pollution. Since agrofuels' share in transport fuels is increasing, it seems important to have a close look at the change of tailpipe emissions of key pollutants when agrofuels are used compared to when fossil fuels are used.

It was found that studies on agrofuels' tailpipe emissions are scarce and sometimes contradictory. Thus it is not easy to have a clear understanding of the impacts of the use of agrofuels on air pollution compared to fossil fuel use.

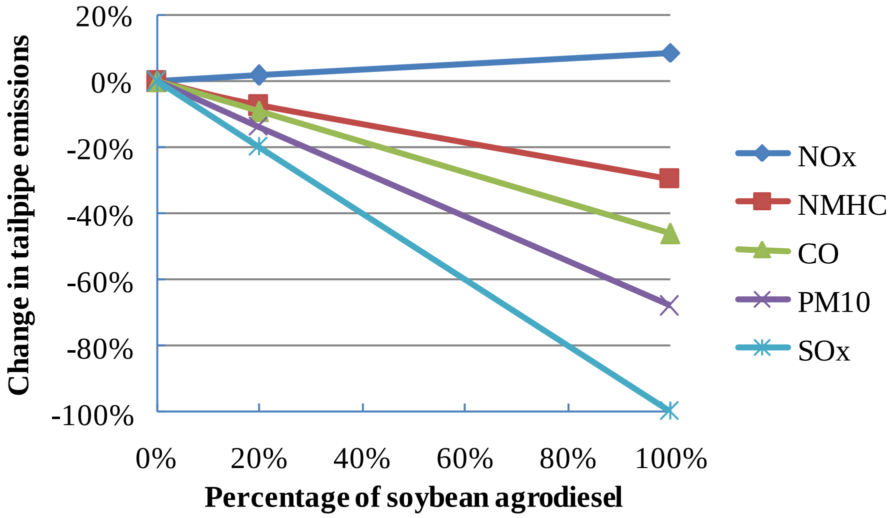
- Straight Vegetable Oil tailpipe emissions:

Since SVO is not widely used as an agrofuel, researches on the emissions of air pollutants from its combustion are rare (Rutz & Janssen, 2007). SVO combustion might reduce some levels of air pollutants compared to fossil diesel (such as carbon monoxide CO), but in the same time SVO combustion produces higher levels of some pollutants (hydrocarbons HC, nitrogen oxides NO_x – above European Euro III norms - and particulate matter PM - just under the Euro III limit) (Daey Ouwens & Adriaans, 2007) as well as some pollutants that are known to be lungirritating such as acrolein and other aldehydes. Technical adaptations of engines to run on SVO might help increase combustion efficiency and thus reduce air pollution.

- Agrodiesel tailpipe emissions:

According to a 1998 US study (Sheehan *et al.*, 1998), tailpipe emissions from urban buses running on B20 (20% agrodiesel) and B100 (100% agrodiesel) - B stands for 'biodiesel' - showed a significant decrease in tailpipe emissions of several pollutants compared to fossil diesel. The use of pure soybean agrodiesel was deemed to totally eliminate sulphur oxides (SO_x) emissions, reduce the emissions of particulate matter lower than 10 microns (PM10) by nearly 70%, the emissions of carbon monoxide (CO) by 45% and the emissions of non-methaneous hydrocarbons (NMHC) by 30%. However, an increase by nearly 10% was observed for nitrogen oxides (NO_x) emissions (cf. figure below). It should be noted that agrodiesel emissions of particulates may be lower in quantity than those of diesel but the substances are different and thus lead to different health effects[21].

Figure 17: Average change in tailpipe emissions of blends of soybean agrodiesel for heavy-duty highway engines



Source : Personal graph made with data from Sheehan *et al.* (1998)

A 2009 study found that tailpipe emissions from construction vehicles using soybean agrodiesel showed even better results, and even reduced NO_x emissions compared with fossil diesel (Pang *et al.*, 2009).

However, rising emissions of formaldehyde, acrolein, and acetaldehyde (which are not currently limited by norms) were demonstrated for agrodiesel combustion compared with fossil diesel combustion (Rutz & Janssen, 2007).

[21] Cf.
http://webarchive.nationalarchives.gov.uk/+/http://www.dft.gov.uk/pgr/roads/environment/rtfo/289579?page=13

Finally, Mazzoleni *et al.* (2007) show that real-world agrodiesel is not necessarily in compliance with agrodiesel standards as it can contain high concentrations of free glycerin. According to this study, the use of real-world agrodiesel fuels could entail an increase in nearly all air pollutants compared to diesel emissions.

- Agroethanol tailpipe emissions:

According to Leong *et al.* (2002) ethanol use could decrease some emissions of VOC (Volatile Organic Compounds) such as benzene, toluene and m-xylene but could lead to an increase in emissions of formaldehyde and acetaldehyde which are both ozone-precursors. These results were also found by Jacobson (2007) who even warned that increased levels of acetaldehyde and formaldehyde emissions due to rapid increase in ethanol fuel use might lead to higher ozone levels and thus ethanol would be a "greater overall public health risk than [petrol]". Formaldehyde and above all acetaldehyde emissions from ethanol fuel use were found by Jacobson to largely increase as well as PAN (peroxyacetyl nitrate) emissions, an eye irritant that can also damage crops (Jacobson, 2007). Acetaldehyde and PAN emissions increase is acknowledged on the US RFA (Renewable Fuel Association, that is the US ethanol lobby) webpage but it is claimed on this same webpage that "these compounds are more than offset by reductions in formaldehyde, a toxic air contaminant many times more harmful than acetaldehyde"[22], which contradicts the two studies above-mentioned.

However, it should be noted that due to differences in engines, climatic conditions (air pressure and humidity) and experiment protocols (such as speed of the vehicle, etc.) there is no single answer about whether air pollution from agrofuel use is more or less damaging to the environment and human health when compared to the fossil fuels they substitute for.

3.1.2 Agrofuels' lifecycles

Looking at environmental issues associated with the end-use of a product (for instance tailpipe emissions and potential toxicity of agrofuels) is not sufficient to have a good idea of all the impacts related to this product. One also needs to look at impacts associated with the production of the end product to have a better picture of its actual impacts.

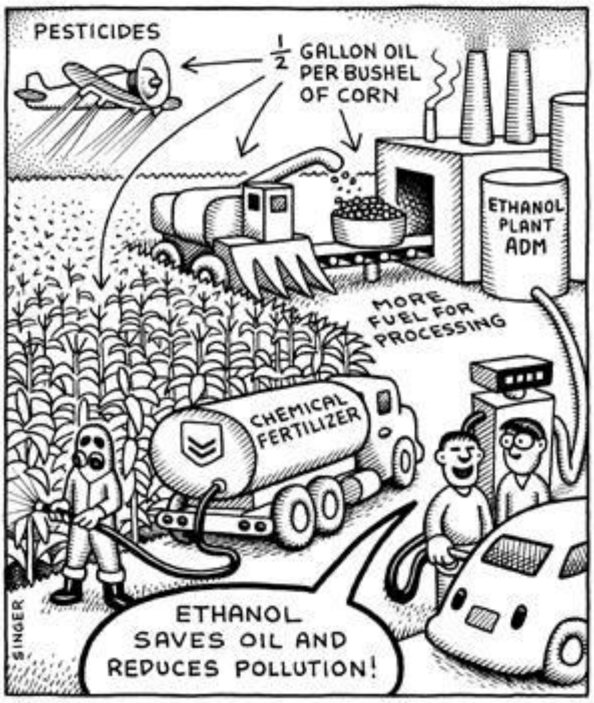
Thus, the concepts of embodied energy (or grey energy), embodied carbon emissions and virtual water were introduced to help represent some specific impacts of products along their production path. They mean the quantities of energy, carbon emissions or water that were used to obtain the end product. These data can give information to consumers on specific

[22] Cf. http://ethanolrfa.org/pages/ethanol-facts-environment

environmental impacts of the products they purchase. In the same way, for the picture of agrofuels' environmental impacts to be comprehensive, one needs to look at them on a life-cycle basis.

Agrofuel are generally made from agricultural feedstocks grown with intensive industrial farming practices. Intensive farming requires large inputs of agrochemicals (fertilisers and pesticides) to produce crops and has large impacts on biodiversity, soil, water and air quality (cf. drawing below).

Figure 18: Ironic cartoon "Ethanol saves oil and reduces pollution"



Source: Drawing from Andrew B. Singer's series "No Exit" http://www.andysinger.com/

3.1.2.1 Introduction on Life-Cycle Assessments

Life-Cycle Assessments (LCAs) are a practical tool commonly used to assess the environmental impacts of a product or a service. LCAs are made following the guidelines of the ISO 14040 and 14044 norms and follow four distinct phases (ISO, 2006b; a):

- the '**Goal and Scope**' phase in which the object of study or 'functional unit' is defined. For agrofuels, it is usually 1 MJ of agrofuel or sometimes the unit of agrofuel needed for a given car to cover 1 km. The choice of goal of the study influences the breadth of the system boundaries (cf. 3.1.2.3).

- '**Life Cycle Inventory**' (LCI), which consists in the collection of data associated with environmental impacts within the system boundaries and a modelling of the system. Allocation rules are chosen for by-products during this phase (cf. 3.1.2.4).

- '**Life Cycle Impact Assessment**' (LCIA). Collected data are converted into units that show the contribution of the analysed product to environmental impacts. Environmental impacts that can be measured in agrofuel LCAs are (von Blottnitz & Curran, 2007):

- natural resource depletion (fossil energy and ore use but also land and water use)
- global warming potential (measured in gCO_2e = gram of CO_2 equivalent)
- ozone depletion potential (the emission of ozone-depleting gases can reduce the protective ozone layer within the stratosphere)
- acidification potential (SO_2 and NO_x are gases that can react with water vapour in the atmosphere to form acids and thus result in 'acid rains')
- eutrophication potential. Eutrophication is an increase in aquatic plant growth due to fertilisers leached from land to water surfaces, resulting in fish death and decrease in aquatic biodiversity.
- ecological toxicity potential (potential of chemicals to cause harm to flora and fauna)
- human toxicity potential (potential negative human health effects of chemicals released in the environment)
- smog formation or photochemical ozone creation potential (POCP) (NO_x, CO, CH_4 and other volatile organic compounds – VOC – can react in the presence of heat or sunlight to form tropospheric ozone that can lead to negative impacts on human health and the environment measured relative to ethylene and expressed in ethylene equivalent)

- '**Interpretation**'. A sensitivity analysis is performed and a conclusion is drawn from the results of the LCIA.

LCAs have become so widespread that LCA can now be considered as a discipline as suggests the 'International Journal of Life Cycle Assessments' the first issue of which was released in 2007.

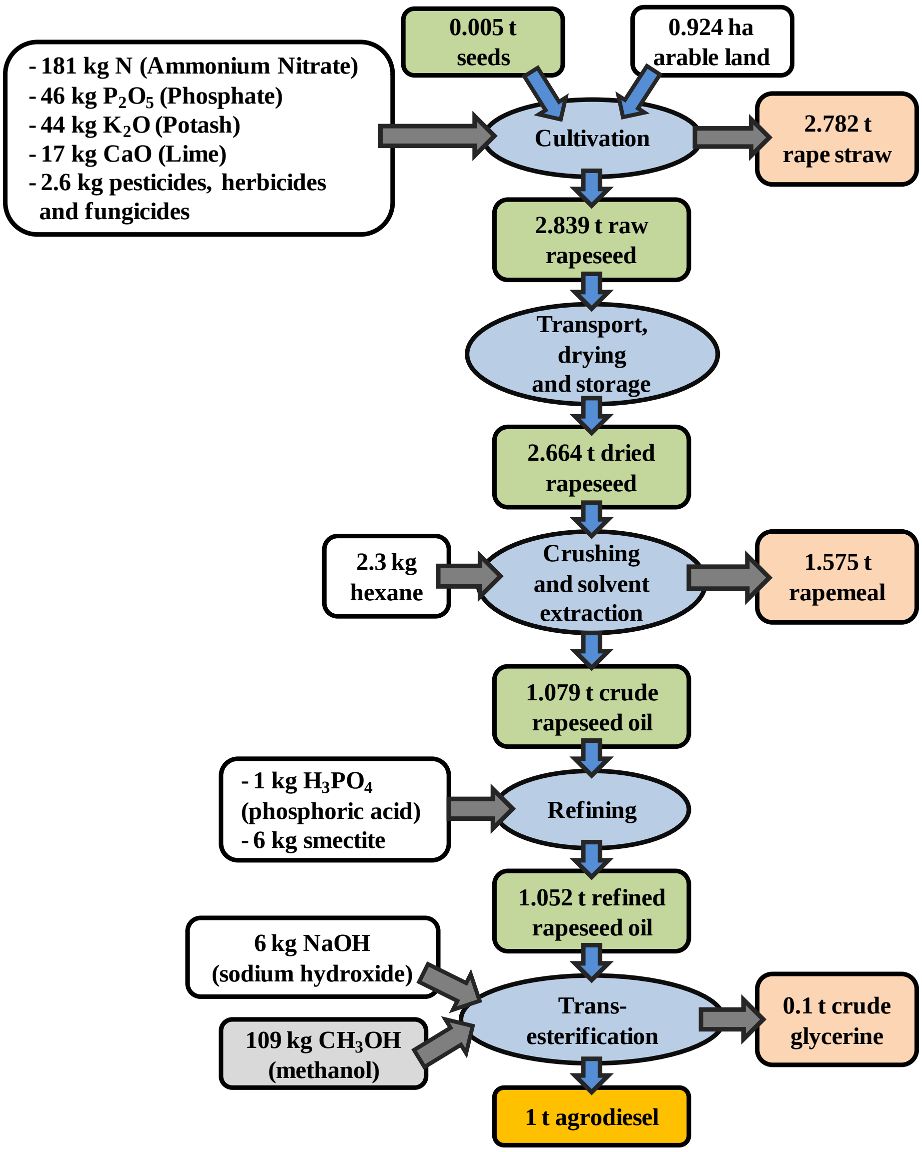
3.1.2.2 Physical flowchart of agrofuels: example of RME production

For agrofuels' lifecycle GHG emissions to be assessed, a thorough understanding of their production chain is needed.

Due to the wide range of results on agrofuels' GHG emissions it was thought more practical to focus on one specific agrofuel. Oilseed Rape (OSR) agrodiesel (also known as Rapeseed Methyl Ester - RME) was chosen because it is the main agrofuel that is produced in Europe (particularly in France and Germany).

The following figure is a simplified flowchart showing a typical production chain of RME when it is produced in the UK. In this flowchart, steps of production are in blue ovals while the agricultural products extracted from the original rape seeds to finally produce RME are in green rectangles. Physical inputs that do not directly enter in the chemical composition of the final molecule of RME are in the white rectangles while inputs that enter in RME's chemical composition are in grey rectangles. Finally, by-products are in pale red and RME is represented in orange.

Figure 19: Simplified physical flowchart of the production of one tonne of RME in the UK



Source: Personal drawing with masses of inputs calculated using data from Elsayed *et al.* (2003)

For the diagram to be readable, energy inputs were not represented even though they are numerous, occur at each step of the production process and come from various types of fuels (diesel, natural gas, heavy fuel oil, electricity - thus a mix of fuels -, etc.). For instance, diesel is needed to fuel tractors during the cultivation step while electricity and heat are required for the transesterification step, etc. Moreover, this production chain does not include the steps between RME production and its end-use (combustion in a car engine).

This figure clearly shows that numerous products are needed for the production of agrodiesel, from fertilizers and pesticides in the cultivation phase to methanol for the transesterification of refined rapeseed oil into Rape Methyl Ester (RME).

The figure also shows that several by-products necessarily accompany the production of OSR agrodiesel. Actually, in terms of weight, agrodiesel only represents a small fraction of the total output of the production chain - **about 18%** - since 2.782 t of rape straw, 1.575 t of rapemeal and 0.1 t of glycerin are produced for each tonne of agrodiesel. If one does not count straw in the agrofuel chain output, OSR agrodiesel still represents only **37%** by weight of the output of the production chain.

Fertilizers and pesticides that appear in the top left white rectangle are typically used in these quantities in intensive agriculture, which is the main source of OSR for agrodiesel production. Hexane is a solvent that is used to remove as much rapeseed oil as possible from rapemeal to get the highest possible quantity of oil from dried rapeseed. Smectite is a type of clay that is used to bleach crude rapeseed oil while phosphoric acid is used to degum crude rapeseed oil.

All the physical inputs as well as the energy inputs have associated environmental impacts (including embedded GHG emissions) that need to be taken into account to determine the overall environmental impacts of RME agrodiesel.

If one comes back to the decision of OFGEM not to consider agrodiesel as a renewable energy source when it is partly made of fossil methanol (OFGEM, 2009) (cf. chapter 2), it seems rather illogical that agroethanol is considered renewable since its production also requires large quantities of fossil fuel input in its lifecycle, such as fossil fuels for nitrogen fertiliser production as well as fossil energy inputs all along the agroethanol production chain.

3.1.2.3 System boundaries

The **direct environmental impacts** of a specific agrofuel theoretically encompass all the environmental consequences associated with each step of the agrofuel chain that can be attributed to the agrofuel as well as the relative burdens carried by all the inputs relative to their production and the production of the facilities where they are produced.

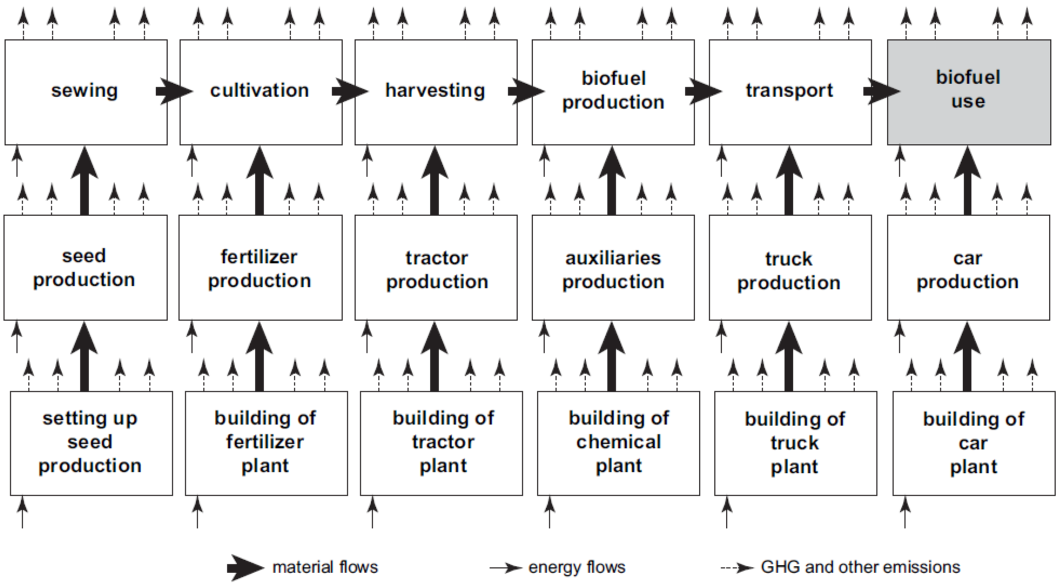
For instance, RME's environmental impacts include the impacts of:
- making cropland available for OSR cultivation (eventually changing land use, cf. 3.1.3.3);
- producing OSR seeds and sowing them into the soil;
- using tractors and farm machinery and the relative burdens linked to the production of tractors and farm machinery as well as those of the production of the plants where tractors and farm machinery are produced;
- using agrochemicals (fertilisers and pesticides), whether the impacts are on-field or off-field, producing agrochemicals and the relative share in the impacts linked to the production of the plants where these agrochemicals are produced;
- the uptake of atmospheric CO_2 that is absorbed by OSR when it grows (during the photosynthesis process);
- the agriculture practices used for OSR cultivation (type of ploughing, land management, crop residue management, etc.);
- using facilities for seed crushing, rapeseed oil refining, rapeseed oil purification and esterification and the relative share in the impacts linked to the construction of these facilities;
- the credit from the production of by-products;
- using trucks for the transportation steps and the relative share in the impacts linked to the production of trucks as well as those of the production of factories where trucks are produced;
- using other chemicals and the relative share in the impacts linked to the production of the plants where these other chemicals are produced;
- the relative share in the impacts linked to the production and maintenance of vehicles and roads. Although usually ignored (except from Zah's paper (Zah *et al.*, 2007) - cf. figure 20 - that includes car production), this part should also be associated with agrofuels and has considerable environmental impacts;
- the GHG (mostly CO_2) released during the combustion of the agrofuel when the car runs. Tailpipe CO_2 emissions are often supposed to be offset by the CO_2 that was absorbed during photosynthesis.

Direct environmental impacts are more or less distant from the actual cycle of carbon atoms from photosynthesis to agrofuel combustion. Macedo differentiates three levels of energy flows in the sugarcane production chain (Macedo *et al.*, 2004):

- level 1: "direct consumption of external fuels and electricity";
- level 2: "additional energy required for the production of chemicals and materials used in agriculture and industrial processes (fertilisers, lime, seeds, herbicide, sulphuric acid, lubricants, etc.)";
- level 3: "additional energy necessary for the manufacture, construction and maintenance of equipments and buildings".

Similarly, the figure below shows that the physical flowchart of agrofuels can extend well beyond the boundaries suggested by the simplified physical flowchart of RME production in figure 19.

Figure 20: Schematic flow diagram of material flows, energy flows and pollutant emissions in the agrofuel production chain



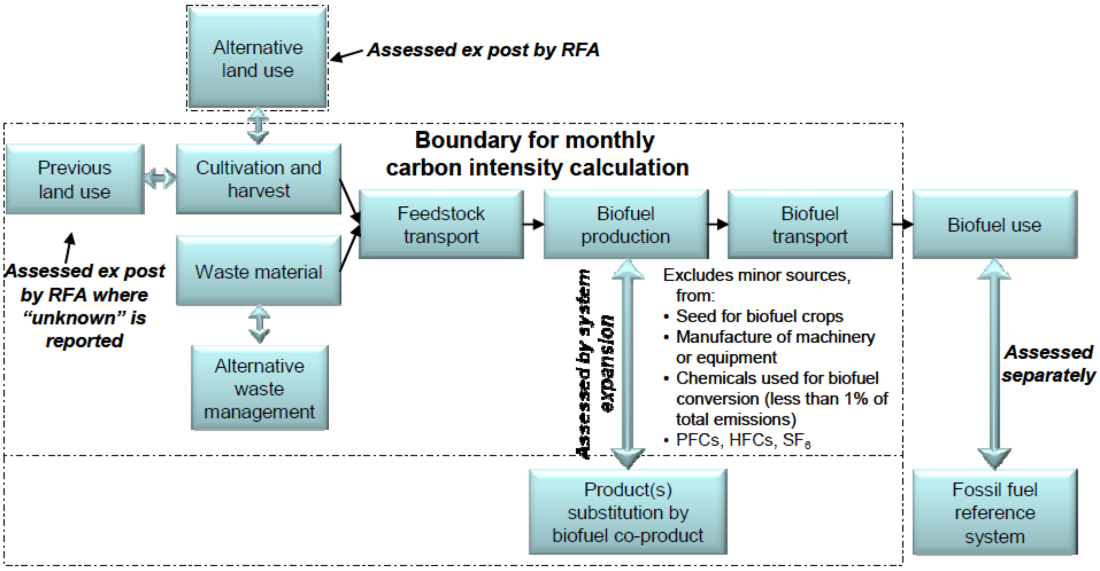
Source: (Zah *et al.*, 2009)

To be more comprehensive, one could even add to the above diagram the construction of roads and transport infrastructure that are associated with agrofuels (cf. RME's environmental impacts listed earlier).

The top line of the above diagram represents what could be called '**direct primary steps**' while the second line shows '**direct secondary steps**' and the bottom line '**direct tertiary steps**' associated with agrofuels. In this context, 'primary', 'secondary' and 'tertiary' should not be understood in terms of importance but in terms of proximity of the visible lifecycle of the end-product (here agrofuels).

Some studies suggest that the amortization of infrastructure can range between 4 and 8% of increase in fossil energy per unit of agrofuel produced (Bio Intelligence Service, 2008a). However, when infrastructure amortization represents a GHG intensity that is lower than 5% of the total GHG emissions of the agrofuel, a ‘cut-off’ rule applies and the emissions are ignored. Thus most GHG LCAs assume that tertiary emissions are negligible (cf. figure below), whereas only few secondary impacts are taken into account (such as fertiliser production and seed production).

Figure 21: Sketch of the boundaries chosen by the UK RFA (Renewable Fuels Agency)



Source: (Bauen *et al.*, 2008)

In order to improve the transparency and objectivity of studies that assess agrofuels' environmental implications, it seems that more research is needed on the assessment of the importance of the impacts linked with direct secondary and tertiary steps of agrofuels production.

3.1.2.4 By-product allocation

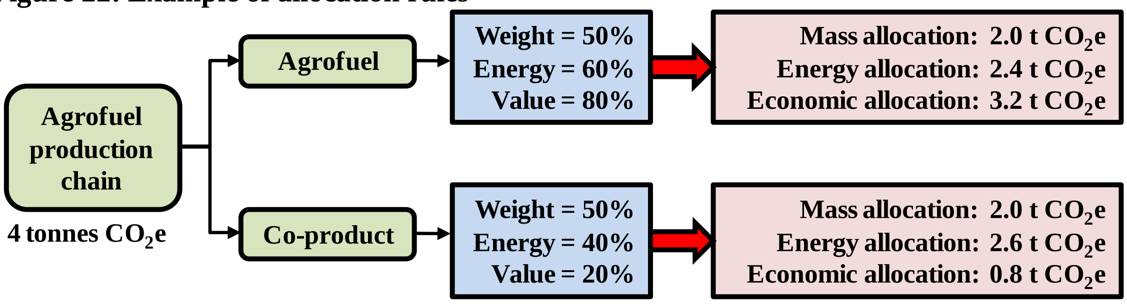
As said earlier, agrofuels only represent a fraction of the outputs of their production chains. Since by-products are produced along with agrofuels, it seems logical that they are assigned a share of the environmental burden of the production chain (although some studies do not attribute any environmental impact to agrofuel by-products but this seems to be unfair because such by-products are used for some purpose and thus can avoid some environmental impacts).

Different methods are used to take by-products into account:

- mass, energy and economic allocation;
- substitution or system expansion.

The most straightforward by-product treatment consists in assigning a share of a specific environmental impact to the agrofuel and the by-product depending on their respective share in the total mass of products (mass allocation), the total cost of the products (economic allocation) or the total energy content (energy allocation). A theoretical example is given in the figure below with GHG emissions but this can apply to any environmental burden associated with a production chain:

Figure 22: Example of allocation rules

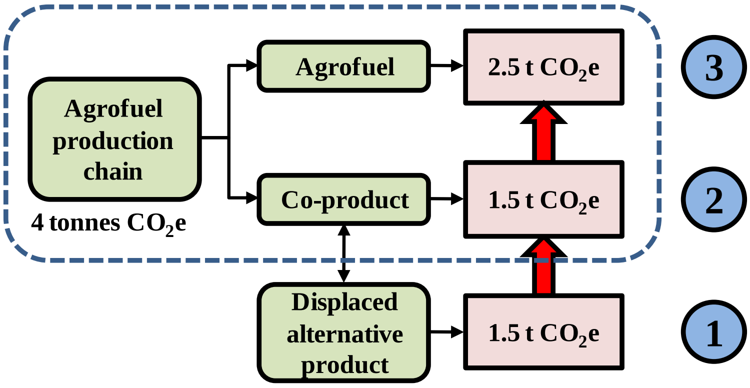


Source: Personal diagram

Mass and energy allocations correspond to a fixed ratio for a specific agrofuel feedstock, unless this feedstock is modified or extraction technologies evolve, which eventually provides new proportions of by-products compared to agrofuel feedstock. On the opposite, economic allocation is highly dynamic since the relative prices of agrofuels and by-products of a specific chain can fluctuate rapidly.

The other type of by-product treatment consists in determining an alternative product (outside the agrofuel chain boundaries) that is displaced because of the production of the newly created by-product produced at the same time as the considered agrofuel. Once this product is identified, its environmental burden we are interested in (for instance its GHG-intensity) is assessed (step 1) and assigned to the agrofuel by-product (step 2). The remaining specific environmental burden (GHG emissions in this example) is then assigned to the agrofuel output of the chain (step 3) (cf. figure below).

Figure 23: The system expansion approach or substitution allocation

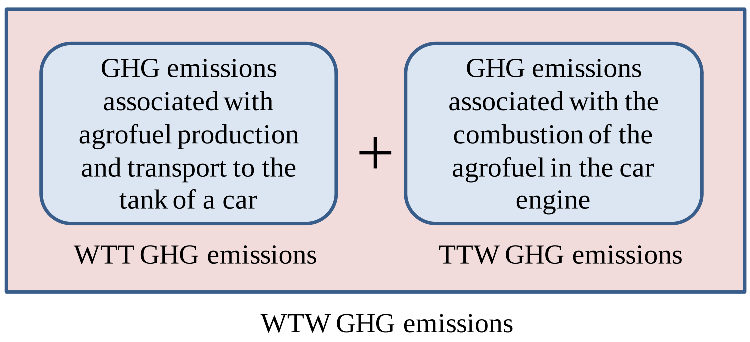


Source: Personal diagram

3.1.3 Agrofuels' direct GHG emissions

With similar GHG tailpipes (Tank-to-Wheel or TTW) emissions than fossil fuels, how can it be that agrofuels are promoted for reducing GHG emissions? This is because the emissions one sees from the tailpipes of a car running on an agrofuel only represent the visible part of GHG emissions linked to agrofuel use. Agrofuels also have associated GHG emissions along their production (called Well-to-Tank or WTT emissions). Since their feedstock is generally mostly based on organic material that is built from CO_2 taken from the atmosphere, a carbon credit associated to photosynthesis is attributed to agrofuels. If WTT GHG emissions of agrofuels are lower than those of fossil fuels (which are associated to their exploration, exploitation and transport, etc.), then agrofuels' WTW (Well-to-Wheel) GHG emissions will be reduced against fossil fuel WTW GHG emissions.

Figure 24: WTW = WTT+TTW



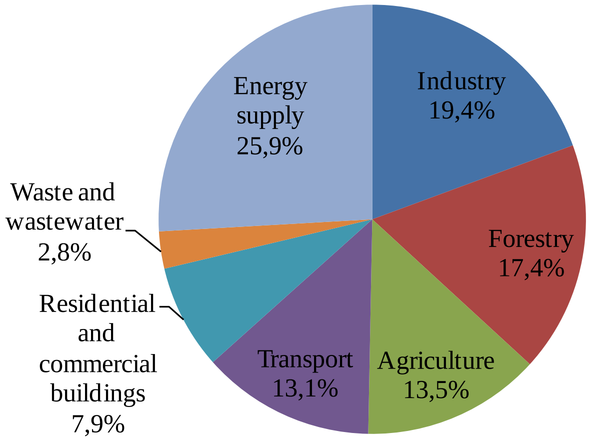
Source: Personal diagram

This section aims at presenting how agrofuels' direct GHG emissions are usually measured.

3.1.3.1 Agrofuels' GHG emissions are not always assigned to the transport sector

As seen in the introduction, transport GHG emissions are increasing worldwide and road transport is highly dependent on fossil fuels. According to the AR4 (4th Assessment Report of the IPCC – Intergovernmental Panel on Climate Change), transport accounted for 13.1% of anthropogenic GHG emissions in 2004 (cf. pie chart below).

Figure 25: Share of global anthropogenic GHG emissions by sector in 2004



Source: Adapted from Ribeiro *et al.* (2007)

The classification of GHG emissions by sector as reported in the above diagram hides the fact that the different sectors are highly interdependent. For instance, a study from the FAO (Steinfeld *et al.*, 2006) estimated that livestock alone was responsible for about 18% GHG emissions measured in CO_2 equivalent, which is more than total agriculture GHG emissions. This is because it was estimated that a large part of GHG emissions due to livestock derives from land-use-change (especially deforestation, therefore entering the 'forestry' category) caused by the expansion of pastures and arable land for feedcrops. Moreover, considerable amounts of GHG emissions associated to livestock come for instance from livestock processing (industry), refrigerated transport (transport sector) as well as from burning fossil fuels to produce mineral fertilizers used for feed and pasture (energy supply and industry), etc. Thus, livestock overlaps several sectors, at least agriculture, forestry, transport, industry and energy supply.

In the same way, liquid agrofuels belong at first sight to the transport sector since they are used as transport fuels. Moreover, agrofuels are promoted by most policies for reducing GHG emissions from transport (EU, US, France, UK, etc.). However, agrofuels are by definition fuels made from agriculture biomass. Therefore, some of their GHG emissions come from their agriculture phase. As can be seen in the figure above, agriculture is not a benign sector GHG-wise since it is the 4th GHG emitter (13.5% of global anthropogenic GHG emissions in 2004) after energy supply, industry, forestry, and just above the transport sector. Agrofuels also impact forestry since their production could put pressure on deforestation (cf. discussion on indirect land-use change in section 2 of this chapter).

Since TTW CO_2 emissions of agrofuels (or the biomass part of fuels that are only partly derived from biomass such as agrodiesel made with fossil fuel-derived methanol or agro-ETBE and agro-MTBE made with fossil fuel-derived isobutylene) are equal to the amount of photosynthesised CO_2 taken from the atmosphere during the growing phase of the feedstock, some official statistics assume that agrofuels' associated GHG emissions are worth zero in the transport sector.

- For instance, Eurostat data show surprisingly constant transport GHG emissions for EU-15[23] (member countries in the EU prior to the accession of ten Eastern European countries on 1 May 2004) between 2003 and 2007 although transport energy demand has constantly increased in this region during this period[24]. Emails exchanged with Eurostat staff made us understand that TTW CO_2 emissions of agrofuels had been excluded from transport GHG emissions (because agrofuels are assumed to be renewable) while their associated WTT GHG emissions had not been assigned to transportation, but to the relevant sectors (agriculture, industry, etc.) where these steps occurred, "to avoid double-counting".

- GHG emissions seem to be assigned in a similar way by the International Energy Agency (IEA) since the World Energy Outlook (WEO) 2007 (IEA, 2007) includes agrofuels in the tables showing world transport energy demand but does not include agrofuels in the tables on world transport CO_2 emissions, which are equal to the addition of CO_2 emissions from coal for transport, oil for transport and gas for transport. CO_2 emissions from agrofuels are simply not assigned in transport CO_2 emissions.

Since agrofuels are precisely promoted for reducing GHG emissions of the transport sector it seems more appropriate to count agrofuels' associated GHG emissions in the transport sector. To get a more accurate picture and to avoid double-counting, agrofuels' GHG emissions should be gathered and assigned to transport rather than to other sectors.

[23] Cf. http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tsdtr410
[24] Cf. http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=ten00100&plugin=1

3.1.3.2 GHG emissions by step of the agrofuel life

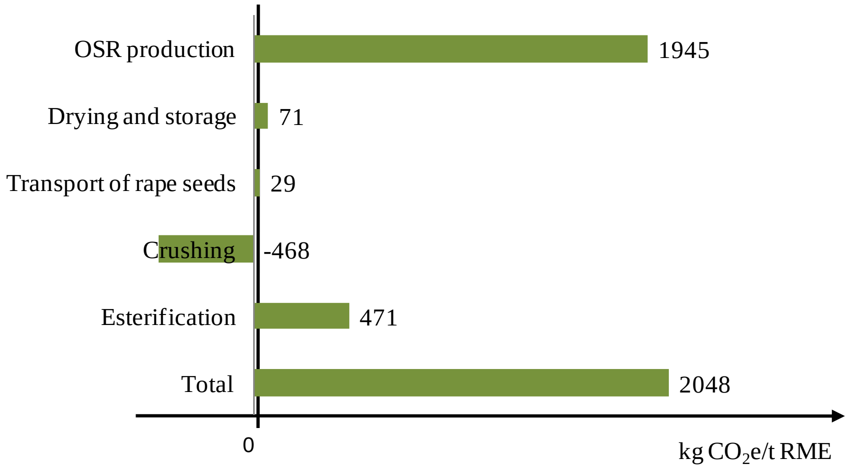
After RME's production (cf. RME's production chain in figure 19 in 3.1.2.2), blending, distribution and end use are the final steps of RME's life, which can thus be divided into 5 phases:

1) The **agriculture phase** (here cultivation of OSR and getting of rape seeds) that includes the choice of the land for feedstock cultivation;
2) **Preparation of the feedstock** (here: drying, storage and crushing of the rape seeds, solvent extraction and refining to obtain rapeseed oil – which can be an agrofuel on its own for adapted engines) which includes eventual transport steps from field to crusher;
3) **Preparation of the agrofuel** (here: conversion of refined rapeseed oil into RME);
4) **Blending and distribution** to the pumps;
5) **End use** of the agrofuel = combustion (for instance combustion of B5 in a car engine).

Transport steps that happen right after the making of an intermediate product are associated with the consecutive phase. For instance the step 'transport of refined rapeseed oil to the place where rapeseed oil is transesterified to produce agrodiesel' is included in the phase that was called 'preparation of the agrofuel'.

The following diagram represents the distribution of UK RME's GHG emissions according to the steps of its production.

Figure 26: UK RME default GHG emissions by step according to the RFA methodology



Source: Personal diagram made with data from RFA (2009b)

One can notice that the UK RFA (Renewable Fuels Agency) does not take account of the blending and distribution steps of agrofuels lives. Although the RFA claims its "GHG calculation methodology is based on a well-to-wheel approach" (RFA, 2009a) GHG calculations are only made until the refining/blending facility. This is probably because only the agriculture phase and the phases of preparation of the feedstock and of the agrofuel are specific to agrofuels while distribution and end use are common with fossil fuels (blending probably induces limited GHG emissions) .

The first observation that comes from this diagram is that RME is not carbon-neutral (or GHG-neutral). According to the RFA, 1 tonne of UK RME emits about 2 tonnes (2,048 kg) of carbon dioxide equivalent. Thus, proponents that claim that agrofuels are ‘carbon-neutral’ (cf. chapter 2) probably ignore GHG emissions associated with agrofuels’ production as analysed in LCAs.

These emissions can be compared to the GHG emissions for diesel according to the same RFA paper:

- diesel emission factor = 0.086 $kgCO_2e/MJ$
- RME’s Lower Heating Value: LHV = 37.2 MJ/kg

thus RME emission factor = 2,048/37.2 = 0.055 $kgCO_2e/MJ$

- GHG emission reduction from RME production compared with fossil diesel:

(0.086-0.055)/0.086 = 36%

Thus according to the RFA, average UK OSR RME provides 36% GHG reduction compared with fossil diesel. One can also say that GHG emissions of RME amount to 64% of fossil diesel GHG emissions.

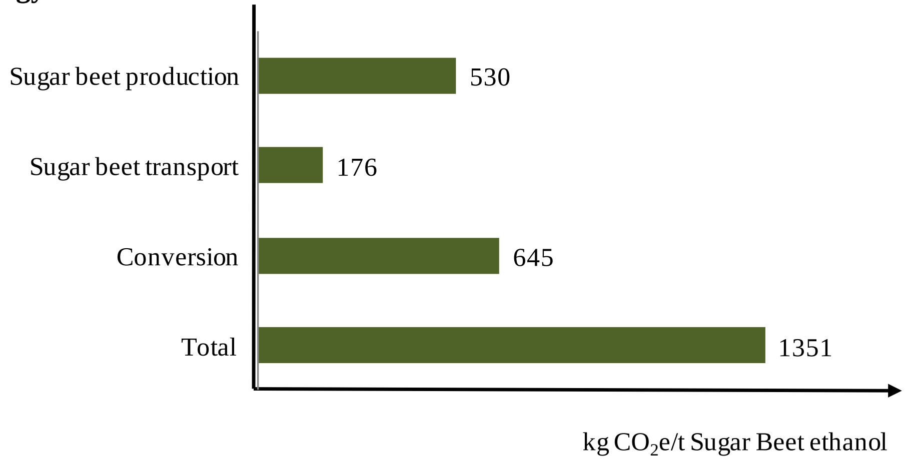
The second observation is that OSR production (which we call the agriculture phase) is the step during which most GHGs are emitted while the drying/storage and transport steps have little associated GHG emissions. Indeed, the agriculture step is very GHG-intensive especially because large quantities of nitrogen fertilisers are used in conventional agriculture (cf. next section).

Finally, the ‘crushing’ step has negative GHG emissions. This is because rapemeal that is produced during this step is assumed to substitute for US soy meal as an animal feed (system expansion approach). RME thus gets a GHG credit for the product that rapemeal substitutes for.

It should be noted that the distribution of GHG emission according to the different steps of agrofuel production is highly dependent on the feedstock, the actual practices, energy sources used for energy inputs along the agrofuel chain as well as the agrofuel route (agrodiesel or agroethanol).

Indeed, the following diagram made for UK sugar beet with the RFA 2009 default values gives very different patterns:

Figure 27: UK Sugar Beet ethanol default GHG emissions by step according to the RFA methodology



Source: Personal diagram made with data from RFA (2009b)

This time, conversion is the most GHG emitting step because considerable amounts of natural gas are needed to distil ethanol that comes from sugar fermentation (only 75.2 kg of ethanol is formed from the fermentation of 1 tonne of sugar beet according to RFA's figures). The credits gained from the production of sugar beet pulp and lime as by-products (assumed to respectively substitute for UK wheat as animal feed and agricultural lime) from the conversion step are not sufficient to compensate for the emissions from natural gas and electricity inputs.

On the opposite side, Brazilian sugar cane yields 63.5 kg ethanol per tonne of sugar cane but the energy-intensive distillation step is assumed to be carbon-neutral because its energy input entirely comes from electricity from the burning of bagasse, a residue from sugar cane cultivation (RFA, 2009b). This is not the default scenario for South African sugar cane ethanol (idem for Pakistan) for which coal is assumed to be the energy source for the distillation step, which leads to a high default value for the GHG-intensity of South African sugar cane ethanol (above petrol GHG-intensity).

It should be noted that sugar cane crops are often burnt prior to harvesting since it is a convenient method that helps speed up sugar cane harvesting, especially when it is not mechanically harvested. However, methane (CH_4) and nitrous oxide (N_2O) are highly potent GHGs that are released in small quantities when sugar cane trash is burnt. Their emissions from trash burning are taken into account in the RFA methodology (RFA, 2009a) even though their share in sugar cane ethanol associated GHG emissions is marginal.

The next sub-sections will focus on two main issues relating to agrofuels that can lead to large GHG emissions: Land-Use Change and N_2O emissions.

3.1.3.3 Land-Use Change GHG emissions

The life of any agrofuel starts with the choice of the land for the cultivation of its feedstock. If the land is not arable, whether it is a forest, a prairie or another type of land, then happens what is usually called **land-use change (LUC)**. If the land chosen is already arable, then there is no direct land-use change but an indirect one may occur. Such **indirect land-use change (iLUC)** is a very complex notion on which we will come back in section 2 of this chapter.

The first critics of agrofuels came in 2005 with articles of Fred Pearce in the New Scientist (Pearce, 2005) and of George Monbiot in the Guardian (Monbiot, 2005a) that blamed European agrofuel policies for being incentives for the expansion of palm oil plantations in South East Asia and soybean fields in Brazil at the expense of the rainforest. Palm oil companies are thought by some of having an important role in the Indonesian fires of 1997-1998 (Wakker, 2005) that burnt large areas including vast deposits of peat (areas of very high carbon density) resulting in considerable emissions of CO_2 (Schimel & Baker, 2002). Such fires contributed to an equivalent of 13 to 40% of annual emissions from fossil-fuel combustion (Page *et al.*, 2002; Schimel & Baker, 2002). Moreover, up to 20% of oil palm plantations in South-East Asia are on peat soils that used to be covered by peatswamp forests but that were drained for oil palms to be grown (Kaat & Silvius, 2007), which triggered an oxidation process resulting in large emissions of CO_2. Peatland fires associated with drainage and degradation put Indonesia in 3rd place after the USA and China in the global CO_2 emission ranking (Hooijer *et al.*, 2006).

European policies are currently very favourable to agrofuels but the European arable area is limited. Since the land required to meet the European agrofuels objectives for 2020 exceeds the amount of available arable land for bioenergy production without harming the environment in the EU (estimates from EEA (2006)), some European grazing land could be ploughed up to increase the arable area. However, such practice reduces organic carbon stored in the soil and results in very large CO_2 emissions per hectare of ploughed up grazing land (73 tCO_2/ha) according to Edwards *et al.* (2007a).

Thus, agrofuels need to be imported to meet the European targets of agrofuel incorporation. In 2009, just 9% of agrofuels sold in the UK under the Renewable transport Fuel Obligation (RTFO) came from feedstocks sourced domestically (RFA, 2010d) while 91% came from imported feedstocks and from feedstocks with ‘unknown’ reported country of origin. However, according to the EEA (European Environment Agency) “the accelerated destruction of rain forests due to increasing biofuel production can already be witnessed in some developing countries” (EEA Scientific Committee, 2008). Indeed, others have reported that some ‘developing’ countries such as Brazil, Paraguay and Indonesia would have huge deforestation programmes to supply the world agrofuel market (Pearce, 2005; Righelato & Spracklen, 2007). Therefore, the EEA Scientific Committee asked for a suspension of the 10 percent agrofuel target in 2020 in the EU.

LUC leads to considerable GHG emissions that are usually calculated with the methodologies provided by the Task Force on National Greenhouse Gas Inventories of the IPCC (2006). LUC GHG emissions are especially large when a forestland is converted to an annual cropland (GHG emissions are lower when forest land is converted to perennial cropland). Moreover, LUC GHG emissions are generally higher for conversions from forestland and grassland in tropical countries than in temperate countries.

The following table based on data from the RFA (2009a) presents the default values for GHG emissions from LUC for some of the main countries that provided agrofuels to the UK market in the 1st year of the RTFO according to the RFA (2010d):

Table 3: GHG emissions from LUC (in tCO_2e/ha)

Country	Forest land to		Grassland to	
	Annual cropland	Perennial cropland	Annual cropland	Perennial cropland
USA	-17	-16	-2	0
Germany	-21	-14	-7	-1
Malaysia	-37	-26	-11	0
Brazil	-37	-26	-11	0
UK	-27	-20	-7	-1

Source: Data from RFA (2009a)

Thus, when LUC GHG emissions are taken into account in agrofuel GHG LCAs, they lead to much higher GHG intensities as can be seen in the following table:

Table 4: Default GHG intensity of selected agrofuels including GHG emissions from LUC (in gCO_2e/MJ of agrofuel)

Agrofuel	Origin	Land converted from:		
		Cropland	Forestland	Grassland
Soy agrodiesel	USA	58	1,038	173
OSR agrodiesel	Germany	48	409	168
Palm agrodiesel	Malaysia	47	202	100
Sugar cane ethanol	Brazil	25	238	99
Sugar beet ethanol	UK	50	281	110

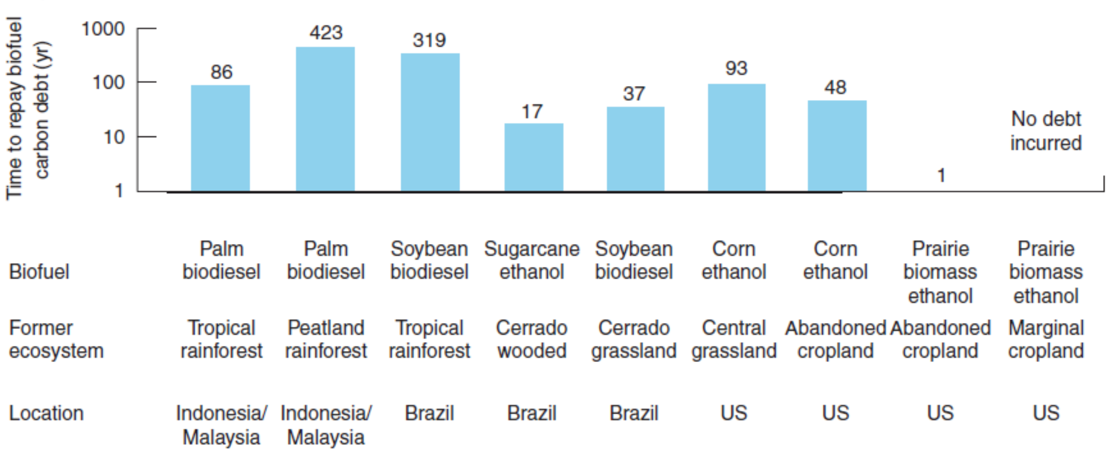
Source: Data from RFA (2009a)

These GHG intensities should be compared with the default GHG intensities chosen by the RFA (2009a) for diesel (86.4 gCO_2e/MJ) and petrol (84.8 gCO_2e/MJ). Thus, according to the last table, all main agrofuels sold in the UK have higher GHG emissions than equivalent fossil fuels as soon as LUC occurs, whether the former land use was forestland or grassland.

A carbon payback calculation is proposed by the RFA (RFA, 2008a) to have an idea of how many years are needed for agrofuel yearly GHG savings (if any) to offset the GHG emissions due to LUC: Carbon payback time = (Total carbon loss as a result of LUC)/(Amount of carbon saved annually).

Fargione developed a slightly different approach (Fargione *et al.*, 2008) by defining a 'biofuel carbon debt' that corresponds to the amount of carbon that is released because of LUC during the first 50 years after LUC, multiplied by a factor corresponding to the part of the debt that is allocated to the agrofuel (by economic allocation). Then this 'biofuel carbon debt' is divided by the expected annual GHG emission savings provided by the specific agrofuel, which gives an idea on the 'time [needed] to repay the biofuel carbon debt' (cf. figure below for the results from this paper):

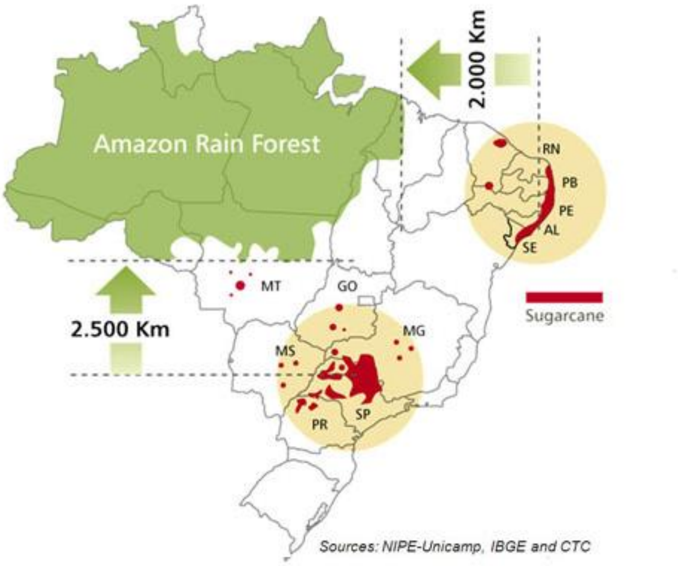
Figure 28: Examples of carbon payback time for several agrofuels



Source: (Fargione *et al.*, 2008)

Aware that LUC is an important issue in term of GHG emissions, the UNICA (Brazilian Sugarcane Industry Association) published the following map on its website in order to show that sugar cane production has no (direct) impact on deforestation of the Amazon rainforest and thus that the GHG intensity of sugar cane agroethanol is lower than that of petrol.

Figure 29: Brazilian sugarcane producing regions are far from the Amazon rainforest



Source: (UNICA, 2008)

However, the 'Cerrado', a wooded savannah extending on a large part of Brazil, that includes parts of the beige areas of the above map is currently undergoing two or three times as much annual deforestation as the Amazon (Sawyer, 2008) but is surprisingly not represented on the above map (as well as the 'Mata Atlantica' or 'Atlantic forest'). The overlap of the sugarcane production areas and these 'high carbon value' areas can be seen when looking at the figure below (which shows the main ecosystems in Brazil) and compare it with the one above.

Figure 30: Map of Brazil ecosystems

Source: (Krug & Rudorff, 2009)

3.1.3.4 Fertilisers' GHG emissions

On top of H_2O (water), CO_2 (carbon dioxide) from the atmosphere and sunlight, thirteen elements are commonly thought to be essential for plant growth (Yara International ASA, 2009):

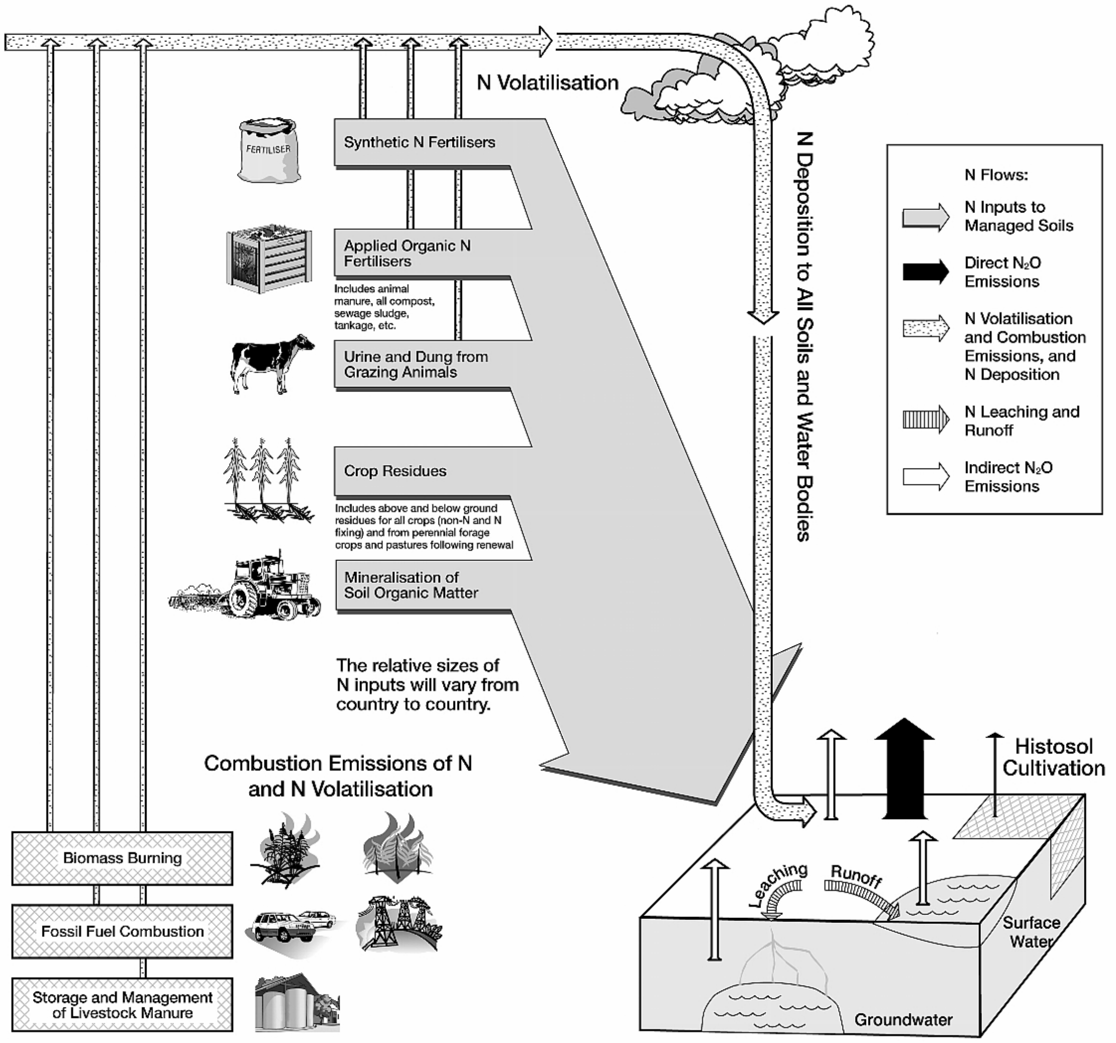
- major nutrients: N (Nitrogen), P (Phosphorus) and K (Potassium);
- secondary nutrients: Ca (Calcium), Magnesium (Mg) and S (Sulphur);
- micro-nutrients: Fe (Iron), Mn (Manganese), B (Boron), Zn (Zinc), Cu (Copper), Mo (Molybdenum) and Cl (Chlorine).

Major nutrients are usually provided to crops in the form of mineral fertilisers in large quantities in conventional agriculture. Whereas P and K fertilizers are commonly sourced from mineral rocks (rock phosphate and potash respectively), nitrogen fertilizers are usually produced from ammonia (NH_3) that is synthesised after a Haber-Bosch process that combines dihydrogen H_2 (usually obtained from fossil natural gas) and N_2 from the atmosphere. Since the Haber-Bosch process is energy-intensive and requires natural gas as a source of H_2, nitrogen fertilizers have a much higher GHG intensity than most other fertilizers. Moreover, applying nitrogen fertilizers to agriculture crops is associated with emissions of nitrous oxide (N_2O) that is not only a recreational drug (sometimes called 'happy gas') but also a very potent GHG. Its 100-year GWP (Global Warming Potential) is worth 298 according to the IPCC AR4 (Forster *et al.*, 2007), making N_2O one of the main contributors to agriculture GHG emissions.

According to de Klein *et al.*, "nitrous oxide (N_2O) is produced naturally in soils through the processes of nitrification and denitrification (de Klein *et al.*, 2006). Nitrification is the aerobic microbial oxidation of ammonium (NH_4^+) to nitrate (NO_3^-), and denitrification is the anaerobic microbial reduction of nitrate to nitrogen gas (N_2). Nitrous oxide is a gaseous intermediate in the reaction sequence of denitrification and a by-product of nitrification that leaks from microbial cells into the soil and ultimately into the atmosphere." Nitrogen fertilisers' applications bring ammonium and/or nitrate and thus largely influence nitrification and denitrification, resulting in N_2O emissions. Most agrofuel LCAs rely on the 'IPCC Tier 1' approach and assume that the rate of N_2O emissions is proportional to the rate of nitrogen fertiliser applied (Bauen *et al.*, 2009).

The following figure shows sources and mechanisms involved in N_2O emissions.

Figure 31: Schematic diagram illustrating the sources and pathways of N that result in 'direct' and 'indirect' N_2O emissions from soils and waters



Source: (de Klein *et al.*, 2006)

N_2O emissions are calculated by multiplying quantities of N applied by the emission factors (EF) of the sources of N_2O expressed in kg N_2O-N/kg N, i.e. the mass of nitrogen in N_2O emitted by mass of nitrogen applied.

According to the Tier 1 approach N_2O emissions from nitrogen fertilisers are divided into the following 2 categories (de Klein *et al.*, 2006):

- 'direct' N_2O emissions resulting from the addition of mineral fertilisers (EF1 = 0.01 kg N_2O-N/kg N);
- 'indirect' N_2O emissions from NH_3 and NO_x volatilisation ($Frac_{GASF}$.EF4 = 0.001 kg N_2O-N/kg N)) and 'indirect' N_2O emissions from the leaching and runoff of N fertilisers ($Frac_{LEACH}$.EF5 = 0.00225 kg N_2O-N/kg N)) (Bio Intelligence Service, 2008a).

N.B.: In this thesis, the wording '**indirect**' is already used for indirect Land-Use Change that is explained in section 2 of this chapter. To be consistent, the terminology '**secondary**' is preferred to 'indirect' for N_2O emissions from the volatilisation of NH_3 and NO_x and '**off-site**' is thought more appropriate to define N_2O emissions from the leaching and runoff of N fertilisers.

Thus the total emission factor associated with nitrogen fertiliser application (according to IPCC Tier 1) is worth:

Total EF = Direct EF + Secondary EF + Off-site EF = 1% + 0.1% + 0.225%

→ Total EF = 1.325%

This means that 1.325% by mass of N applied as fertilisers ends up in N in N_2O emissions according to the IPCC Tier 1 methodology.

When this emission factor is used for LCA calculations and because of its large GWP the contribution of N_2O emissions to the total GHG emissions of agrofuels is generally considerable (cf. following table):

Table 5: N_2O contribution to agrofuels' GHG emissions

Type of agrofuel	N_2O contribution to total GHG emissions	N_2O contribution to agriculture GHG emissions
Wheat Ethanol	26%	40%
Maize ethanol	21%	33%
Sugar cane ethanol	21%	44%
Rapeseed oil Methyl Ester	34%	43%
Sunflower oil Methyl Ester	19%	30%
US Soy Methyl Ester	35%	53%
Pure Rapeseed Oil	42%	43%

Source: Adapted from BioIS 2008 (2008a)

But agrofuels do not only produce GHG emissions, they also cause large environmental impacts that need to be taken into account in serious environment policies.

3.1.4 Agrofuels' direct non-GHG environnemental impacts

> *"LCAs typically report that bio-ethanol results in reductions in resource use and global warming; however, impacts on acidification, human toxicity and ecological toxicity, occurring mainly during the growing and processing of biomass, were more often unfavourable than favourable."* (von Blottnitz & Curran, 2007)

Agrofuels are promoted for their potential to reduce GHG emissions compared with fossil fuel use. Therefore, most agrofuels LCAs focus on their lifecycle GHG emissions. However, agrofuel production also potentially leads to numerous environmental impacts. Direct environmental impacts associated with agrofuel production are too numerous, too diverse and too dependent on feedstocks and practices to allow any generalisation. This section aims at presenting some direct primary non-GHG environmental impacts linked to agrofuel production. Secondary and tertiary impacts as defined in 3.1.2.3 are not included to avoid overcomplexification. Currently, most of such impacts (especially tertiary impacts) are never calculated for agrofuels even though they are directly associated with their production and use.

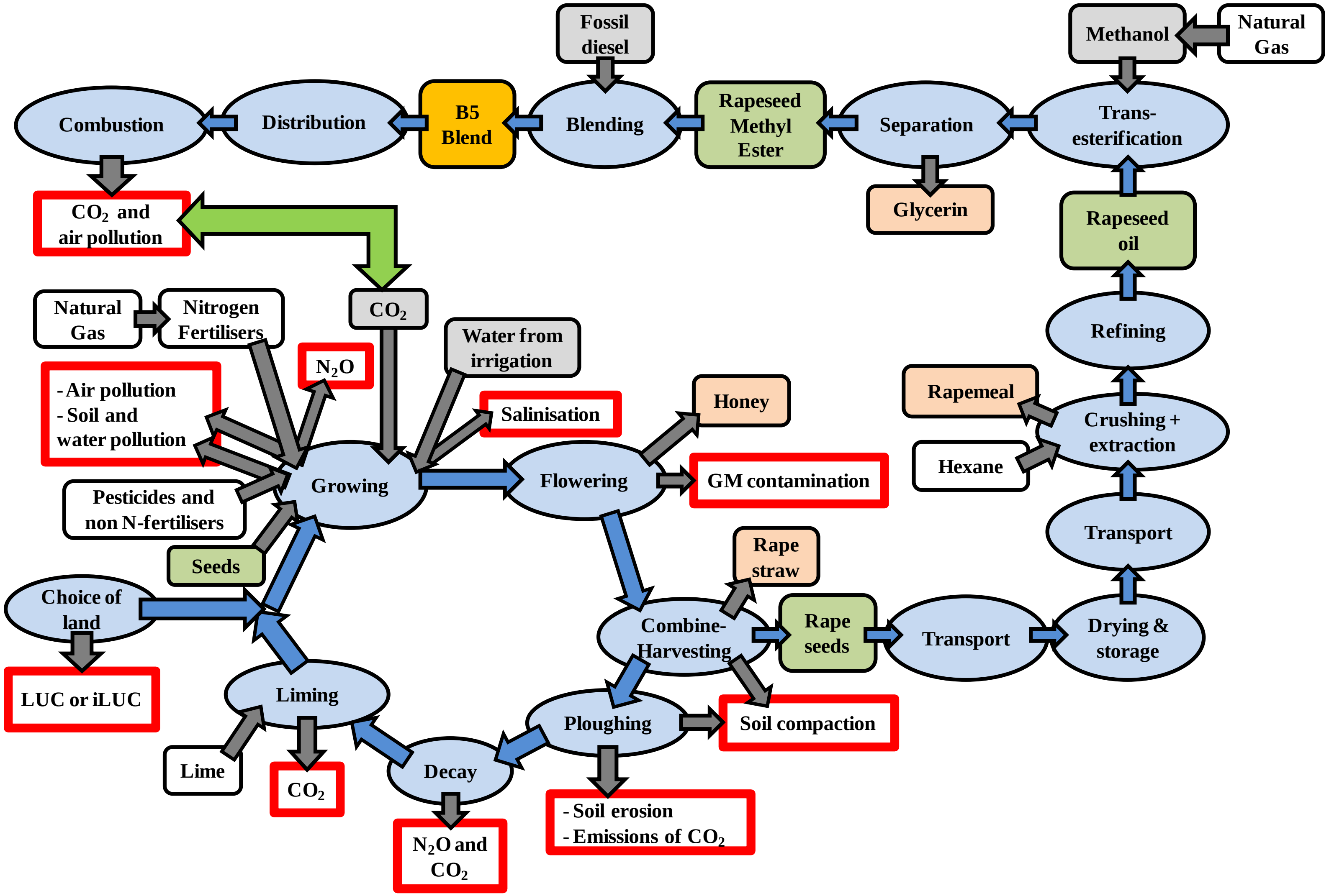
3.1.4.1 RME's direct primary non-energy related environmental impacts as an example to base upon

Agrofuels' direct environmental impacts are as diverse as agrofuels' feedstocks and the practices used along their production chain. It was thought more convenient to start with potential environmental impacts associated with RME production and use. To have a broad understanding of the direct primary environmental implications of RME, steps of the entire life of RME agrodiesel were determined. Then, the potential environmental impacts arising from each specific step were investigated.

The results of this research are summarised in a simplified flowchart presenting some non-energy related direct primary environmental impacts of the agrodiesel part of a 'B5' blend of RME and fossil diesel. GHG emissions and air pollution due to the numerous energy inputs along the production chain were not included in the flowchart to avoid an overloading of information. These energy inputs include for instance fossil diesel to run farming machinery for drilling, agrochemicals spraying, harvesting, ploughing, liming, (etc.) or fossil diesel to run trucks for the several transportation steps along the production chain as well as electricity and heat for the industrial steps of processing (extraction of oil from rapeseeds and transesterification). Actually, all steps apart from 'flowering' and 'decay' require energy inputs and thus result in GHG emissions and air pollution (on-site or off-site if electricity is used).

In this diagram, steps that result in environmental impacts are in blue ovals. RME agriculture intermediates are in green rectangles; physical inputs entering the composition of RME are in grey rectangles while inputs that do not directly enter in the chemical composition of the RME blend are in white rectangles. Finally, by-products are in pale red rectangles and environmental adverse impacts are framed in red. The final B5 blend is in orange.

Figure 32: Some potential environmental impacts of the RME part of a 'B5' blend along its lifecycle



Agroethanol and agrodiesel are produced from a wide range of agricultural feedstocks and after a wide range of agricultural and industrial processes. Moreover, even for one agrofuel from one specific feedstock, practices associated with every step of the production chain can vary widely and thus may result in different types of environmental impacts. However, it was thought interesting to make a general list of all agrofuels' potential environmental impacts so that agrofuels are not only seen in terms of GHG emissions (and potential GHG emissions reduction compared with fossil fuels) but also in terms of non-GHG environmental impacts. Unless specified, the following listing of environmental impacts relates to all agrofuels but some impacts are exemplified for RME (upon which the reasoning was built) or for some other specific agrofuels.

3.1.4.2 Agriculture phase impacts of agrofuel production

The first phase of the life of an agrofuel is its cultivation (the agriculture phase). Looking at the agriculture phase roughly comes down to having a close look at conventional (intensive) agriculture's impacts. The agriculture phase is a particularity of agrofuels in that their fossil fuel equivalents are not sourced from agricultural feedstocks but from oil fields.

- **Choice of the land for cultivation**

LUC (and iLUC) can lead to considerable impacts on the environment such as the following:

- LUC can cause very large **GHG emissions** (IPCC, 2000; 2003) (cf. 3.1.3.3);

- LUC can directly cause **air pollution** for instance in the case of the burning of forestland or peatlands;

- LUC has **adverse impacts on biodiversity**. For instance, set-aside land is known in Europe to provide benefits to wildlife. Its conversion to agrofuel feedstock production has negative effects on biodiversity (Anderson & Fergusson, 2006).

In Indonesia and Malaysia, deforestation and habitat fragmentation due to palm oil expansion threaten the survival of many species (Keeney & Nanninga, 2008) such as the orangutan in Borneo and Sumatra. Such showcase animal has a considerable impact on consumers' choices. Therefore, a logo was developed to tag food products that are free from palm oil and thus considered not to contribute to threats on the orang-utan. The following logo can be found on some oatcakes packaging in the UK:

Figure 33: "Orang-Utan Friendly - Free from Palm Oil" logo

Source: from http://www.wildaboutoats.com/

As for Brazil, ethanol plants are mostly concentrated in the state of São Paulo in the Atlantic Forest biome (cf. figures 29 & 30 page 77), one of the top five biodiversity hotspots on Earth (Keeney & Nanninga, 2008) while soybean (used as animal feed or increasingly for agrodiesel production) cultivation has become a major driver for deforestation in the Cerrado and the Amazon region.

- Once land has been chosen for a specific agrofuel feedstock cultivation, there is a risk of **monoculture** - i.e. an important sector is covered with the same feedstock (the interest in agrofuel production has encouraged such practice) - which considerably reduces biodiversity (Biofuelwatch *et al.*, 2007; GRAIN, 2007; Smolker *et al.*, 2008). Increase in monoculture also alters **agricultural landscapes** and the **ecosystem services** they provide, such as insect biocontrol (Landis *et al.*, 2008) and can accelerate the spread of crop diseases (Zhu *et al.*, 2000).
- LUC, especially when forests are converted to cropland, leads to **soil degradation and loss of topsoil**, which in turn can cause **floods** or **mudslides** (Bradshaw *et al.*, 2007).
- In areas vulnerable to desertification, LUC can be irreversible (AEA Technology plc., 2008). Moreover, oil palm plantations that were settled on former peat land are often **abandoned** after circa 25 years because of **soil exhaustion** (Edwards *et al.*, 2008) which becomes what is often called 'abandoned/idle land' (cf. chapter 4).
- Local LUC can also lead to **regional-scale LUC impacts**. Indeed, agrofuel feedstock expansion along with livestock feed expansion could push towards a forest **tipping point** in the Amazon basin (Nepstad *et al.*, 2008) after which the Amazon forest could be replaced by savannah-like vegetation.

- **Drilling**

- Once land is chosen for cultivation, seeds need to be **drilled**. Modern agriculture uses machineries such as tractors to drill. Tractors run on fossil fuels (usually diesel) and thus emit **air pollutants and CO_2**. Their use can also lead to **soil compaction and degradation**.
- Furthermore, drilling **genetically modified seeds** will cause the development of GM plants (GM OSR in the case of RME) that can have large but so far very poorly understood consequences on ecosystems.

It should be noticed that GM products could be better accepted for agrofuel production than food production (Biofuelwatch *et al.*, 2007) because GM agrofuel feedstocks would not directly cause adverse impacts on consumer health. However, their impacts on ecosystems should not be dismissed.

- Moreover, when **non-native energy crops** are introduced, there is some risk that they could spread in the wild, because they lack natural predators (Edwards *et al.*, 2007a). For instance, jatropha is sometimes thought to be **invasive** outside of Mexico and could thus replace native vegetation and reduce biodiversity (Keeney & Nanninga, 2008).

- **Spraying of agrochemicals**

  "[Agrofuels]' impacts in Europe and the USA are likely to be related to intensification and cultivation, i.e. pollution from the use of agrochemicals such as fertilizers, which is typical of agriculture in these regions." (AEA Technology plc., 2008)

- In intensive farming, large quantities of **fertilizers and pesticides** (called agrochemicals) are commonly used. Fertilizers are applied on cropland to provide nutrients to the plants to grow while pesticides are meant to control potential attacks of pests. Such agrochemicals are usually obtained thanks to the **use of fossil fuels and fossil energy** for their synthesis, and are sprayed by agriculture machineries that can lead to **soil compaction, soil degradation** and eventually **erosion** (apart from pesticides sprayed by planes but such practice is extremely energy-intensive). Both synthetic pesticides and fertilizers can lead to **air pollution** but also to **soil and water pollution** through leaching (Hill *et al.*, 2006) and thus **affect biodiversity**.

- Nitrogen fertilizers that contain ammonium NH_4^+ tend to **acidify soils** (Rasmussen & Rohde, 1989; Yara International ASA, 2009) which **reduces the cation exchange capacity** (CEC) of the soil (Barak *et al.*, 1997) and thus the bio-availability of some minerals to the plants unless soil acidity is reduced by the application of lime (Cifu *et al.*, 2004).

Contrary to the common belief saying that N fertilisers help sequester carbon in soils, the use of mineral Nitrogen fertilisers would cause **losses of soil organic carbon** (SOC) because microbial oxidation of SOC is stimulated by N input (Baker *et al.*, 2007; Khan *et al.*, 2007b).

The use of synthetic N fertiliser would also lead to **losses of organic nitrogen**, resulting in **reduced soil productivity** and the need for higher inputs of synthetic N fertilizers (Mulvaney *et al.*, 2009).

- Other fertilizers commonly applied are potash (that brings potassium) and phosphate (that brings phosphorus). Phosphate comes from phosphorite (or rock phosphate) the price of which has considerably increased recently, partly as a result of soaring phosphate demand for agrofuel production which contributes to fears of approaching **peak phosphorus** (Lewis, 2008).

Moreover the application of phosphate fertilisers can lead to the **accumulation of heavy metals** such as Cadmium in agriculture soils (Taylor, 1997) as well as to the **accumulation of radioactive elements** such as radionuclides of Potassium (^{40}K), Uranium (U) and Thorium (Th) (Becegato *et al.*, 2008).

- Besides, sprayed fertilizers are not entirely removed by crops. Leaching of nutrients from fertiliser application can lead to **eutrophication** in downstream rivers, sometimes accompanied with the bloom of toxic algae and can eventually lead to **dead zones** in estuaries and oceans (Diaz & Rosenberg, 2008). Agrofuel production alone is not responsible for this but the **cumulative effects** (Diaz-Chavez, 2008) of intensive farming practices for food and agrofuel production can raise serious environmental issues.

- **Synthetic pesticides**, that include fungicides and herbicides are agrochemicals used in intensive farming to control pest. Such products can be **toxic and dangerous to human health**[25] as well as to **ecosystems**. They can lead to **air pollution**, **soil contamination** and **water contamination**, resulting in plants and animals deaths.

For instance, even though Brazilian sugar cane ethanol is found by most studies to have GHG emissions significantly lower than petrol, it performs badly in terms of ecological impact (when measured with a tool called ‘Eco-indicator 99’) according to Zah *et al.* (2007) because sugar cane production involves the use of Daconate (or sodium hydroxy(methyl)arsenate, a pesticide containing arsenic) that causes high ecotoxicology impacts.

Similarly, some herbicides known to be toxic and banned in several countries are still commonly used in palm oil plantations (such as Paraquat). Their leaching causes severe water pollution and leads to fish kills (Keeney & Nanninga, 2008).

- The use of some pesticides (banned or authorised) can lead to the **accumulation of persistent organic pollutants (POPs)** that remain in the environment (for instance in sediments) for a long time. POP concentration can bioaccumulate in organisms and thus **affect biodiversity**.

- According to Edwards *et al.* (2007a), “break-years encouraged by compulsory set-aside rules tend to reduce pests and diseases, so doing away with it would tend to increase pesticide use”. Thus, the expected intensification of agriculture practices due to the interest in agrofuels may contribute to **higher needs of pesticides**.

- Finally, although GM crops are often hailed as a way to reduce the need for pesticides, the spread of glyphosate-resistant weeds may actually **increase the need for pesticides for some GM crops** (Benbrook, 2009). Moreover, the cultivation of glyphosate-resistant crops sometimes leads to practices where traditional crops suffer from the overuse of glyphosate on surrounding ‘Roundup-ready’ crops (Robin, 2007).

One may notice that ethanol from maize is nicknamed ‘Monsanto moonshine’ in the US since 90% of US maize is GM[26].

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[25] Cf. http://edis.ifas.ufl.edu/pi008

[26] Cf. http://www.policyinnovations.org/ideas/commentary/data/agrofuel

- **CO_2 uptake from the atmosphere**

The green double-arrow of figure 32 page 82 represents the simplified vision found in some commercials presenting agrofuels as carbon-neutral only because their agricultural feedstock contains the same amount of CO_2 than that that is emitted during agrofuel combustion (cf. chapter 2). However, these claims of carbon-neutrality are misleading in that they ignore all other CO_2 emissions as well as other GHG emissions.

During the growing phase, atmospheric CO_2 is absorbed by the plants through photosynthesis and reacts with water from plants to produce carbohydrates stored in plants and dioxygen that is released in the air (cf. equation below).

Figure 34: Simplified photosynthesis equation

$$n\,CO_2 + n\,H_2O + \text{Photons} \longrightarrow (CH_2O)_n + n\,O_2$$

Carbon dioxide	Water	Light energy	Carbohydrate	Oxygen

Biomass carbohydrates formed after photosynthesis are then used for the production of organic material of the plants. Since plants are roughly made from molecules synthesised after the original carbohydrates coming from photosynthesis, biomass can be seen as a solar energy store, the energy of which is released when biomass is burnt. Therefore, biomass is commonly said to be renewable. However, it should be noted that plants also extract minerals from soils. These minerals that constitute 2 to 5% of plants' dry matter according to Bourguignon (Bourguignon & Bourguignon, 2009) are usually not renewed to the soil they come from. This can eventually lead to **soil nutrient decrease** (and thus the need for some fertilisers) while water that is the main constituent of plants can come from non-renewable sources (such as fossil aquifers).

- **Water use**

Crops can be totally rain-fed or can get some water from irrigation.

- In the case of irrigated crops, **conflict with other uses of water** can occur if too much water is used for crop cultivation, especially in arid regions. Irrigation can also lead to **water table declines** in places where rates of groundwater pumping exceed rates of replacement (Roberts *et al.*, 2007). Overpumping of water for irrigation can even sometimes lead to the **salinisation of coastal aquifers**.

- Irrigation, if not done properly, can also lead to **soil pollution**. Indeed, irrigation water contains mineral salts that can concentrate because of evaporation and water use by plants. Salt accumulation can lead to the formation of sodic soils (with high concentrations of sodium) that are associated with **reductions of crop yields** and **soil erosion** as well as **desertification** (Thomas & Morini, 2005; Bourguignon & Bourguignon, 2009).

- The introduction of agrofuel feedstocks that require large amounts of water can create needs for irrigation in water-stressed areas, which can further lead to problems associated with irrigation cited above or can contribute to the **decrease in water surpluses that are available for the environment** (Berndes, 2008; de Fraiture, 2008).

- **Flowering**

Flowering of crops is associated to honey production if bees live in the surrounding of the crop. Thus, OSR honey is sometimes accounted for as a by-product of RME (Gärtner *et al.*, 2003).

But in the case of GM crops, flowering can lead to the contamination of surrounding crops with GM material (Ramsay *et al.*, 1999). Impacts of **GM contamination** on human health and ecosystems are highly uncertain since there is little hindsight on these technologies.

- **Harvesting**

The use of combine-harvesters on wet soils can cause **soil compaction** (AEA Technology plc., 2008) while their diesel consumption causes **emissions of CO_2** and **air pollutants**.

Some plants such as sugar beets require below-surface harvesting that result in so much **soil erosion** and soil degradation (Edwards *et al.*, 2007a) that some recommend such crops are not promoted for agrofuel production (Fritsche *et al.*, 2006).

Sugar cane crops are often set on fire to facilitate harvest, which results in atmospheric pollution and affects human health (Uriarte *et al.*, 2009) but also diminishes the amount of organic matter returned to the soil (Bot & Benites, 2005).

- **Ploughing and soil preparation**

Tillage is usually performed to aerate soils, remove weeds and to bring back crop residues to the soil.

- But tillage can lead to **soil erosion**, especially on steep slopes (AEA Technology plc., 2008). Intense tillage combined with the removal of crop residues also increases soil erosion on flat areas (such practices contributed to the dust storms of the 1930s in the US, famously described in John Steinbeck's 1939 'The Grapes of Wrath'). Bourguignon *et al.* even claim that tillage combined with the use of synthetic fertilisers and pesticides inexorably result in **soil death** (Bourguignon & Bourguignon, 2009).

- Tillage increases soil aeration which in turn increases soil respiration and **emissions of CO_2** while residues left on the soil produce humus and emit less CO_2 (Bot & Benites, 2005).

- The choice itself of annual crops (which is the case for most agrofuels today) rather than perennial crops leaves the soil bare for a large part of the year which also causes **soil erosion** (Baker *et al.*, 2007).

- Deep-ploughing is very **energy-intensive** and thus requires a large use of diesel to fuel machinery.
- Practices such as leaving crop residues on the soil or using cover crops may prevent erosion.

Gärtner *et al.* recognise the positive impact of leaving crops residues on the field – which they call '**preceding crop effect**' – that **reduces the need for nitrogen fertilisers** in particular (Gärtner *et al.*, 2003).

Crop residues ploughed back to the soil might **reduce the need for some nutrients** (for instance P and K) (Woods *et al.*, 2005) but when crop residues have high carbon to nitrogen (C:N) ratios, their **decomposition consumes** nitrogen (Edwards *et al.*, 2007a).

- No-till might **reduce soil erosion** but can require **higher inputs of herbicides** in conventional agriculture.
- It should be noted that the growing of legume crops can increase soil nitrogen and thus reduce the need for nitrogen fertilisers for the subsequent crop.

- **Liming**

Lime application reduces soil acidity (induced by most nitrogen fertiliser application) but leads to CO_2 emissions (Task Force on National Greenhouse Gas Inventories of the IPCC, 2006).

N.B.: Finally, on top of all the impacts identified for each of the above-steps, all agriculture machinery and agrochemicals as well as the plants where machinery and chemicals were produced necessitate natural resources and energy and thus result in numerous adverse impacts on the environment.

3.1.4.3 Impacts of the preparation of the feedstock

This section presents the listing of some environmental impacts associated with the preparation of the agrofuel feedstock (e.g. vegetable oil from oilseeds, sugar solution from wheat, maize, sugar cane and sugar beet) obtained after the agriculture phase.

- **Transport of rape seeds** (or any crude feedstock such as maize cobs or sugarcane stalks)

Engines that run on fossil fuel cause **air pollution** and **emissions of CO_2**. Transportation also requires that specific infrastructure is made or maintained, which has numerous and diverse impacts on the environment.

- **Drying and storage of seeds** (case of agrodiesel from oilseeds and ethanol from cereals)

Seed moisture is removed during drying, which usually requires the use of diesel or electricity and is thus associated with emissions of **CO_2 and air pollutants** (on-site or off-site) or to the production of (off-site) **radioactive wastes** in the case of the use of nuclear electricity.

- **Pressing, extraction and refining** (case of agrodiesel from oilseeds)

\- Fossil fuels and electricity are used to provide energy for the pressing and the extraction of oil from the seeds and are thus associated with **carbon dioxide** and **air pollutant emissions**.
\- Hexane is a solvent that is commonly used to have a higher yield of extraction of rapeseed oil from rape seeds. However, hexane is **toxic** and is then found in rapemeal, the main by-product from the RME chain. Rapemeal is then generally used as an animal feed. Due to the presence of hexane, rapemeal obtained after hexane extraction would probably be toxic for human consumption. But since it is for animal consumption and potentially only affects animal health a moderate amount of toxic chemical is probably not thought to be as much an issue as it would be for human consumption.
\- In the case of palm oil, Fresh Fruit Bunches (FFB) need to be processed within 24 hours of harvest which means that FFB need to be brought to palm oil mills rapidly. Thus palm oil mills are built for about every 4,000 – 5,000 ha of plantation (Wakker, 2005). The construction of numerous palm oil mills obviously leads to **large environmental impacts** (including **large GHG emissions**), especially when mills are set up on former rainforest.
\- Palm Oil Mill Effluent (POME) that is a mixture of water, crushed shells and a small amount of fat residue is produced in large quantities during the extraction of palm oil. It is the largest pollutant discharge into rivers in Malaysia, which causes **organic pollution** and **reduces oxygen availability for aquatic life** (Keeney & Nanninga, 2008).
\- Finally, POME anaerobic treatment is an **important source of methane** (Yacob *et al.*, 2005), a highly potent GHG, that is so far rarely collected for combustion and electricity generation (Wicke *et al.*, 2008).
\- Several chemicals that are used to refine oils produce **toxic wastes**.

- **Milling, hydrolysis** (case of agroethanol from starch and sugar crops)

\- The construction of facilities to mill starch crops has **adverse consequences on the environment**.
\- Starch obtained after milling is hydrolysed thanks to enzymes from yeast into sugar. This process requires a **large amount of water** (10 t of water for 1 t of wheat according to Woods *et al.* (2005)).

3.1.4.4 Impacts associated with the preparation of the agrofuel

Depending on the agrofuel that is produced, two main types of reaction are performed to obtain the final agrofuel:
- trans-esterification of oil with methanol for agrodiesel production
- fermentation of sugar solutions by specific yeasts to produce ethanol.

- **Transesterification** (case of agrodiesel from oilseeds)

- Methanol that is obtained from **fossil natural gas** is commonly used to react with vegetable oil during the transesterification step to produce Fatty Acid Methyl Ester (FAME) and glycerin. Vegetable oils can also react with biomass ethanol to produce Fatty Acid Ethyl Ester (FAEE) but this is rarely done, probably because of the higher cost of agroethanol compared with that of fossil methanol.
- The transesterification process requires heating from electricity or fossil fuels, which results in **GHG emissions** and **air pollution**.

- **Fermentation** (case of agroethanol from starch or sugar crops)

The sugar solution from sugar or starch crops is fermented by yeasts and leads to ethanol production as well as to biogenic CO_2 emissions (considered to be neutral emissions).
Some are tempted to genetically modify yeasts to improve ethanol yields from fermentation (Alper *et al.*, 2006) but this could have **unpredictable consequences on ecosystems** in the event of leakage.

- **Distillation** (case of agroethanol from starch or sugar crops)

Ethanol produced after fermentation is extracted from the fermentation broth by distillation, which requires large amounts of energy. In Brazil, the energy is provided by bagasse, a by-product from sugarcane, and is thus considered carbon neutral, which largely participates in the low calculated carbon intensity of Brazil sugarcane. However, when distillation is performed thanks to the use of GHG-intensive fossil fuels such as coal in the US, this leads to **large GHG emission**s because the distillation step is particularly energy-intensive.

3.1.5 Blending and distribution

Once the agrofuel is produced, it needs to be transported to a refinery where it is blended with its fossil equivalent. Then it is distributed as a blend to the pumps. All transport steps are associated with fossil fuel consumption and thus with **GHG** and **air pollutant emissions**. Transport also requires construction or maintenance of infrastructures (roads, harbours, rail, train stations, etc.) as well as the production of trucks, ships and train wagons which have **numerous environmental impacts**.

3.1.6 End-use

The final step in agrofuels life is the combustion of the agrofuel blend during which carbon dioxide and air pollutants are emitted. Whereas the biomass part of the agrofuel blend emits 'carbon-neutral' biogenic CO_2, the fossil fuel part emits net **fossil CO_2**. As was seen in chapter 2, Agro-ETBE is an agrofuel obtained after the reaction of agroethanol with isobutylene which is a by-product of the oil industry. Thus the isobutylene part of agro-ETBE is considered to emit **fossil GHG emissions**. Moreover, agrodiesel also has a fossil-derived part in it (from methanol). Although this is rarely mentioned, agrodiesel combustion thus also leads to fossil fuel-derived GHG emissions.

Air impacts of agrofuel combustion depend on the type of agrofuel and the type of pollutant (cf. 3.1.1.2). In a complete lifecycle, the end use of agrofuels includes car production and the building of car plants which both have very large environmental impacts (cf. figure 20 in 3.1.2.3). In other words, agrofuels' production is an incentive for car production and thus car factories production, the environmental impacts of which should not be ignored.

3.1.7 Direct social impacts

Although social impacts are not the main focus of this thesis, they were thought to be worth mentioned because several agrofuel certification schemes include social criteria. Moreover, since agrofuels are promoted for 'ethical' reasons (mainly tackling climate change) it seems important that social impacts associated with agrofuels production are taken into consideration. Some direct social impacts associated with agrofuel production are summarised here but this thesis shall concern itself with a selection of environmental impacts, leaving detailed consideration of social effects beyond the scope of this work.

Similarly to the notion of ecological footprint (Wackernagel & Rees, 1996) the notion of a 'social footprint' can be developed. The idea is that a product that is sold needed workers to be produced. Depending on countries, work conditions in the agrofuel industry are not always in compliance with work rights or even to human rights.

For instance, the multinational corporation Louis Dreyfus Commodities (LDC) is thought to employ people who worked in conditions close to slavery in its Brazilian sugarcane plantations[27], while Brazil is a country where child labour for sugarcane harvesting is not uncommon (USDS, 2005). In the same time, Bolloré group is thought of expelling some local people from their land in Cameroon to expand its palm oil plantations (Deltombe, 2009).

Besides, in some regions, agrofuels are thought to bring money to armed forces that violate human rights. For instance, indigenous populations are forced out of certain areas in Colombia by paramilitary and military forces in order to expand oil palm plantations for palm oil agrodiesel production (Biofuelwatch *et al.*, 2007; Smolker *et al.*, 2008; Christian Aid, 2009). Agrodiesel made from palm oil from such plantations looks similar to 'blood diamonds' that are diamonds sold to finance armed groups.

The following advertisements from a 2003 Amnesty International France campaign (called "No trade of weapons and commodities with countries that violate human rights") aimed at denouncing the social cost of the trade of key commodities (diamonds and wood here) with countries that violate human rights ("What price for these diamonds? What price for this piece of furniture?").

Figure 35: 2003 Amnesty International France campaign "no trade of weapons and commodities with countries that violate human rights"

Source:
http://www.amnesty.fr/index.php?/amnesty/s_informer/visuels_et_publicites/publicites_sommaire/non_au_commerce_des_armes_et_des_matieres_premieres_avec_des_pays_qui_violent_les_droits_humains

It sounds relevant to make sure that agrofuels, which are promoted on environmental grounds, do not negatively affect human rights. If no social safeguard is introduced in agrofuel trade, campaigns such as above but targeting some agrofuels could durably impact the image of agrofuels imported from 'developing' countries in general.

[27] Cf. http://www.lemonde.fr/societe/article/2009/11/25/une-entreprise-francaise-accusee-de-travail-force-au-bresil_1272168_3224.html

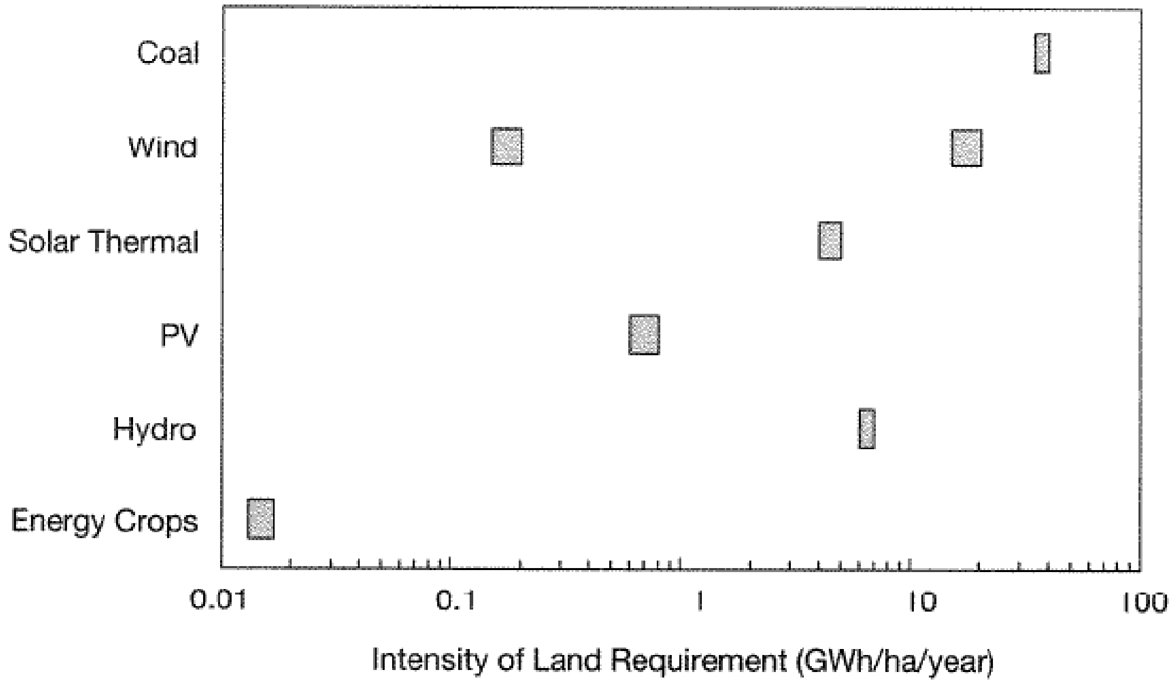
As was seen in this section, numerous environmental impacts (not only GHG emissions!) happen along agrofuels' life. Agrofuels' production also induces secondary and tertiary GHG emissions at each step of their production but these impacts are rarely taken into account. Thus, a sensible environmental policy must be careful not to limit its evaluation of agrofuels' environmental impacts to GHG emissions, and not only to primary GHG emissions, which are just a part of their total 'direct' GHG emissions.

On top of the direct impacts presented in this section, the development of agrofuels causes indirect impacts which are the subject of the following section.

3.2 Potential indirect impacts associated with agrofuel production

Agrofuels are a very land-intensive source of energy. The figure below shows (in logarithmic scale) the intensity of land requirement of several sources of energy for electricity production.

Figure 36: Life Cycle Land Requirements for Electricity Generation



Source: (IEA, 1998)

Energy crops for electricity production appear to be by far the energy source that has the highest requirement of land per output of electricity. Actually, energy crops for agrofuel production (i.e. energy for transport) are even less land-use efficient than when they are used for electricity production (Campbell *et al.*, 2009). Therefore, agrofuels' intensity of land requirement is even lower than that of energy crops for electricity production.

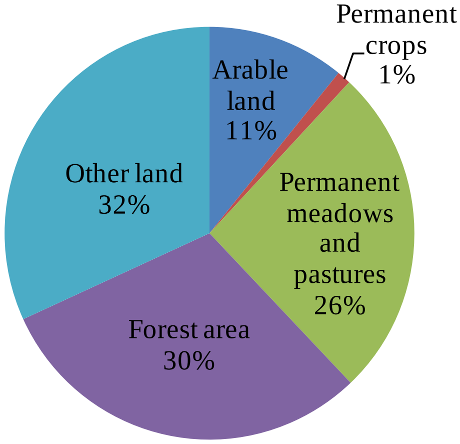
This section aims at presenting some potential indirect environmental consequences (due to the pressure on land use) associated with agrofuels production.

3.2.1 Definition of indirect Land-Use Change (iLUC)

The amount of land that is suitable for agriculture is not infinite. The Earth surface is primarily composed of water (about 71% of water and 29% of land)[28]. Then, the total Earth land that expands on **13.01 Gha** (billion ha) has numerous uses that can be divided into the following (FAO Statistics Division, 2009):

- **4.93 Gha of agricultural land**, including 1.41 Gha of arable land, 0.14 Gha of permanent crop, 3.38 Gha of permanent meadows and pastures
- **3.94 Gha of forest area**
- **4.14 Gha of 'other land'**, which include mainly desert and arid areas (Ezcurra *et al.*, 2006), other biomes non suitable to agriculture and finally settlements and transport infrastructure. This category basically corresponds to all land that does not suit for agriculture.

Figure 37: Global land use distribution



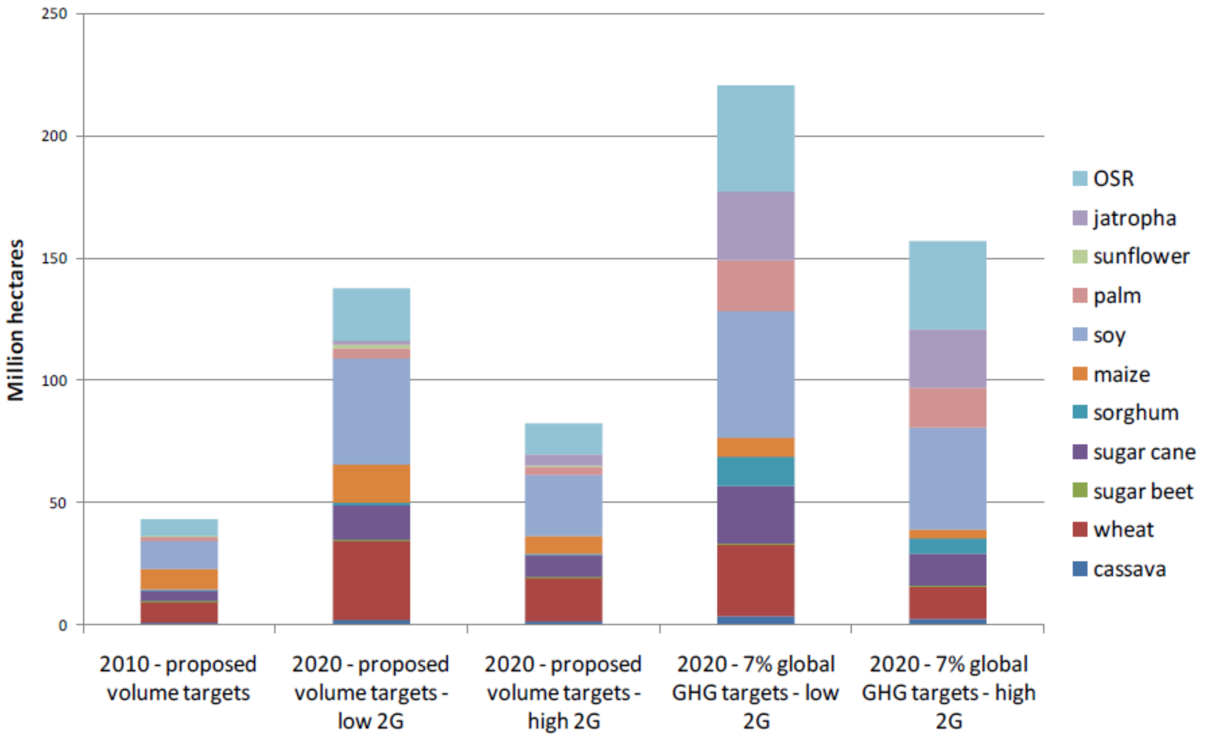
Source: Personal pie chart made with data from the FAO Statistics Division (2009)

The area of the category 'other land' is likely to increase at the expense of other categories since desertification and urban sprawling are moving forward. At the same time, human population is increasing and consumes more food than ever (eaten or wasted) while meat consumption (that is particularly land-intensive) is increasing globally, especially in 'developing' countries (Steinfeld *et al.*, 2006). All these factors contribute to the fact that land is becoming an increasingly sought-after resource. Transport policies that require more arable land for agrofuel expansion thus put an additional pressure on land.

[28] Cf. https://www.cia.gov/library/publications/the-world-factbook/geos/xx.html

Since today's agrofuel feedstocks are only produced on arable land, the area where their production can be done is limited unless pastures or forests are converted to arable land (it is very unlikely that the area of 'other land' decreases in favour of agriculture land).
According to E4Tech (E4Tech, 2008c), the land required for agrofuel production in 2020 could range from 82.3 Mha to 221.9 Mha depending on the political objectives and on the availability of 2nd generation biofuels. This area represents **6 to 16% of the current area of arable land**.

Figure 38: Land area required in different scenarios using BAU yields



Source: (E4Tech, 2008c)

In a purely supply-side frame of mind, few actions are possible to compensate for the need of more land for agrofuels production:
- increase global average productivity of agricultural land;
- reduce set-aside (shorten the average time during which agricultural land is left fallow);
- convert forest or pasture land to arable land directly (LUC) for agrofuel production or indirectly (iLUC) for the production of crops that are displaced because of agrofuel production;
- use more abandoned land or marginal land for the production of agrofuel feedstocks (LUC) or for the production of other agricultural goods (iLUC) displaced because of agrofuel production.

N.B.: In a demand-side frame of mind, consumers' behaviour could change in such a way that land-use per capita for food would be reduced to allow for more land-use per capita for transport agrofuels (cf. chapter 4).

According to Fehrenbach *et al.* (2008a): "**Indirect land use** can be described as the shift of the land use prior to biofuel production to another area where a land-use change occurs due to maintaining the previous level of (e.g. food) production". There are numerous similar definitions of indirect land-use and indirect land-use change (iLUC) (Fehrenbach *et al.*, 2008b; Gnansounou *et al.*, 2008; Fritsche *et al.*, 2009). However, all definitions found were thought to be either too focused (iLUC should not be only associated with agrofuels) or not accurate enough (because by-products are ignored - which often happens in models that try to predict impacts of agrofuels on agriculture markets according to Taheripour et *al.* (2008), because iLUC is not thought of when direct LUC occurs for agrofuel feedstock cultivation, etc.).

We suggest the following definition to general iLUC:

"iLUC corresponds to the **net** land-use change resulting from the displacement of the output of a particular land to another area".

We used the word 'net' because agrofuel production leads to the production of by-products that need to be considered in indirect land-use change calculations (Croezen & Brouwer, 2008; Dehue & Hettinga, 2008; Özdemir *et al.*, 2009) and because the increased pressure on land does not only lead to land conversion but can also be an incentive for higher yields and the reduction of set-aside.

iLUC is a very complex, abstract and dynamic notion that cannot be simply measured. Uncertainties on iLUC are thus extremely high. The aim of this thesis is not to determine and calculate iLUC but more to understand the complexity behind this acronym.

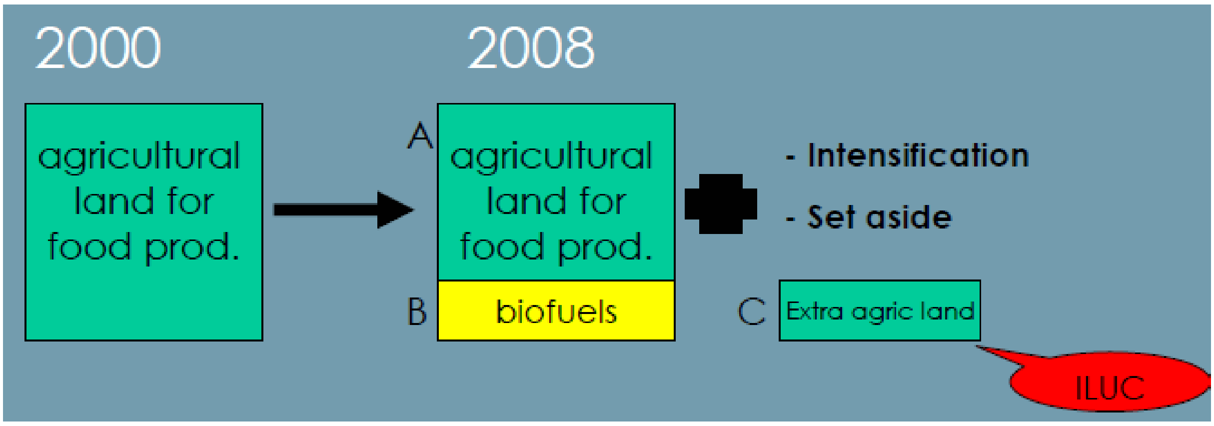
3.2.2 Top-down and bottom-up approaches of iLUC

Although iLUC is often defined in a 'bottom-up' way, the approach used for iLUC modelling is mainly 'top-down' in that there is not much investigation on the direct links between agrofuel feedstock production in a particular place and LUC occurring in another place.

Top-down approach:

Total agrofuels' associated iLUC can be seen as the amount of land that is converted to agricultural land because of agrofuels' increased production and that occurs despite global intensification of agriculture and the global reduction of the time when agriculture land is left fallow (cf. figure below).

Figure 39: Representation of iLUC from agrofuels



Source: (Bergsma, 2008)

However, one of the main challenges in iLUC calculations is to determine links of causality between LUC happening at a particular place and agrofuel production. Indeed, extra agricultural land can also be due for instance to an increase in land demand for food production (because more food is consumed or more land-intensive food is consumed).

Bottom-up approach:

If we assume that the previous level of output needs to be maintained (actually, the agricultural goods demand increases every year globally), in the case of agrofuels, indirect land-use change can be understood as follows (Mercier *et al.*, 2008):

- if the former land use was a forest used for wood production, then the forest is cut down and converted to arable land for agrofuel feedstock production (direct land-use change with very large environmental impacts). The corresponding indirect land-use change is the use of a new area of forest that is needed to produce the wood that is no longer produced by the considered area *adjusted with the land gained by the production of agrofuel by-products (which requires a second investigation on what product such by-products substitute for)*.

N.B.: If the forest was not used for human consumption of good, then direct LUC consists in the destruction of the forest and its conversion to arable land while iLUC that results from this deforestation will be ironically positive in that by-products that accompany agrofuel production are produced and thus reduce the need for more land.

- if the former land use was a pasture for livestock, then the pasture is converted to a land for agrofuel production (arable land for today's agrofuels thus this is a direct land-use change). The indirect land-use change is the use of a new area of pasture or arable land that produces feedstock that substitutes for the loss of the pasture output as animal feed *adjusted with the land gained by the production of agrofuel by-products*.

- if the former land use was arable land for food, feed, fibre (or any other output) production. Then the direct land-use change consists in a change in agriculture practices (which can have large impacts if the former crop is very different from the agrofuel feedstock). Indirect land-use change is the use of a new area of arable land X that produces a feedstock that substitutes for the loss of the displaced previous crop ***adjusted with the land gained by the production of agrofuel by-products***. In a bottom-up approach, investigation is needed to understand what the former use of the land X was before the displaced crop was produced. One could theoretically track land this way and determine what is displaced by the crop that is now produced on land X, (etc.) until one ends up with LUC such as the conversion from forest or pasture to arable land (cf. examples in the following sub-section).

These investigations would theoretically lead at some point to the observation of LUC that can be indirectly attributed to agrofuels. However, this observed LUC needs to be modulated with gains in agriculture productivity and the reduction of set-aside that are incentivised by the increase in agriculture good prices (due to the increased pressure on agricultural land) and thus enable more agriculture production on a fixed area.

However, since numerous factors intervene in LUC at the global scale (timber production, increased pressure on land because of increased consumption of meat in the average global diet, increasing population, etc.), it is uneasy to predict the indirect share of agrofuels in the global LUC burden.

As these examples are theoretical, some more concrete examples are proposed in the next sub-section.

3.2.3 Examples of iLUC in a bottom-up approach

In this section, several types of displacements were exemplified for ethanol from French maize.

- **Maize for animal feed is replaced by maize for agroethanol production**

If one considers one hectare of maize in France and one uses default values given by the RFA (RFA, 2009b) then one hectare yields 8.52 tonnes of maize.
The yield is 0.326 t of ethanol per tonne of maize. Therefore one hectare of maize in France yields on average 8.52 x 3.26 = 2.77 tonnes of ethanol (that is thought to substitute for petrol) and also 0.961 t of maize-DDGS per tonne of ethanol and thus 0.961 x 2.77 = 2.66 tonnes of maize-DDGS per hectare. These results are summarised in the table below.

Table 6: Comparison of the main outputs of maize for feed and maize for ethanol

1 ha of maize for feed production	1 ha of maize for ethanol production
0 t ethanol	2.77 t ethanol
8.52 t of maize	2.66 t maize-DDGS

Source: Personal table with data from RFA (2009b)

Maize-DDGS is mainly used as an animal feed. However, maize-DDGS does not have the same digestibility characteristics depending on the type of animals that are fed (Croezen & Brouwer, 2008).

➢ <u>If maize-DDGS substitutes for maize as animal feed</u>:

According to Wisner (2009) one tonne of DDGS substitutes for:
- 0.45 t of maize in dairy rations;
- 1 t of maize in beef rations;
- 0.85 t of maize in swine rations;
- 0.55 t of maize in poultry rations.

In the US, the main part of maize-DDGS is used for beef, then for dairy, swine and poultry (Wisner, 2009). Using the data from Wisner, we calculate that the average conversion factor of mass of DDGS to mass of maize substituted was 85% in the US in 2008-2009. This means that in the US in 2008-2009, one tonne of DDGS substituted on average for 0.85 t of maize as animal feed (which we call **<u>DDGS-maize substitution ratio</u>**).

If we use this substitution ratio for French maize, 1 ha of maize for ethanol production in France produces 2.66 t of DDGS that is 2.66 x 0.85 = 2.26 tonnes of maize-equivalent. Thus, 8.52 – 2.26 = 6.26 tonnes of French maize were displaced for each hectare of maize cultivation for ethanol production.

If the displacement occurs in France, then 6.26 / 8.52 = **0.73 ha of French maize production are displaced** for each ha of maize cultivation for ethanol production in France. One could also say that that 2.26 / 8.52 = 0.27 ha of French maize are not needed thanks to maize-DDGS produced by maize for ethanol production but the displaced 0.73 ha of maize displaced should not be forgotten.

Since the amount of arable land is limited in France, one could imagine that French forests or pasture lands are cleared and converted into arable land so that the extra amount of arable land needed is made available. The indirect land-use change (iLUC) caused by ethanol production from 1 ha of French maize would be 0.73 ha if the displacement occurred in France, if there was no change in the average yield of French maize and no change in the set-aside policy (fixed amount of set-aside land).

However, agriculture trade is global and the displaced maize can come from anywhere in the world. Actually, the average global yield of maize was 5.11 t/ha in 2008 (FAO Statistics Division, 2009) which is well below the French average maize yield of 8.52 t/ha. If the displacement occurs anywhere in the world, then 6.26 / 5.11 = **1.22 'global average ha' of maize are displaced** for each ha of maize diverted for ethanol production in France.

In other words, the diversion of one hectare of French maize from animal feed to ethanol production would lead to an iLUC of 1.22 global average ha.

- If maize-DDGS substitutes for soybean meal:

If one considers that 1 kg of maize-DDGS substitutes for circa 0.65 kg of soybean meal (average value chosen by Croezen *et al.* (2008)) then 2.66 tonnes of maize-DDGS substitute for 2.66 x 0.65 = 1.73 tonnes of soybean meal.

Since soybean meal is a by-product of soybean cultivation, investigations are needed to determine the area required for the production of a certain quantity of soybean. According to an LCA performed on Argentinean soybean meal with a system expansion approach, the production of 1 kg of Argentinean soybean meal requires 3.6 m^2/year (Dalgaard *et al.*, 2008). Thus 1.73 tonnes of Argentinean soybean meal require (1.73 x 1,000 x 3.6) / 10,000 = 0.62 ha of Argentinean soybean.

Thus, in the case of maize ethanol produced in France, each hectare of French maize for ethanol production displaces one hectare of French maize but avoids the need for 0.62 ha of maize in Argentina.

One could roughly say that 1 – 0.62 = **0.38 ha of arable land are displaced** but as we saw above, agriculture areas do not yield the same amount of crop depending on the country of production.

- **Wheat is replaced by maize for agroethanol production**

In this situation, 1 ha of wheat (for animal or human consumption) in France is replaced by maize for ethanol production.

In France, according to RFA figures, 1 ha of wheat produces 6.99 tonnes of wheat on average (RFA, 2009b) while the average global yield was 3.09 t/ha in 2008 (FAO Statistics Division, 2009).

If one hectare of wheat is displaced for maize ethanol production, then:

- if maize-DDGS substitutes for maize from France and the displaced wheat also comes from France then 1 ha of wheat is displaced and the need for the acreage of maize for feed in France is reduced by 0.27 ha. Net iLUC in France is then equal to 1 **-** 0.27 = **0.73 ha**.

- if maize-DDGS substitutes for maize from anywhere in the world and if the displaced wheat also comes from anywhere in the world, then 2.26 / 5.11 = 0.44 ha of average global maize yield are not needed but 6.99 / 3.09 = 2.26 ha of average global wheat yield are needed to compensate for the loss of wheat (3.09 t of wheat is the world average in 2008 according to FAOSTAT). The net iLUC resulting is 2.26 – 0.44 = **1.82 ha per hectare of French maize**.
- if maize-DDGS substitutes for maize from anywhere in the world but the displaced wheat comes from France, then 1 ha of French wheat is displaced but 0.44 global average ha of maize are not needed. This process results in 1 - 0.44 = **0.56 ha of iLUC**.
- if maize-DDGS substitutes for maize from France and wheat from anywhere in the world, then 2.26 global average ha of wheat are needed but 0.27 ha of French maize are avoided. Thus the net iLUC is worth 2.26 – 0.27 = **1.99 ha**.

Table 7: Hypothetical areas of displaced wheat and avoided maize due to the production of maize ethanol from 1 ha previously planted with wheat in France

Country where the crops are grown	Area of wheat displaced because of the loss of 6.99 t of wheat (in ha)	Area of maize avoided thanks to the production of 2.26 t of maize-DDGS (in ha)
France	1	0.27
Rest of the world	2.26	0.44

Depending on where wheat is displaced and where maize production is avoided thanks to the production of maize-DDGS, net (taking account of by-products) **iLUC ranges from 0.56 to 1.99 ha of land per hectare of maize for ethanol production in France** if we consider that maize-DDGS substitutes for maize and that there is no change in yields nor any change in the amount of set-aside land.

One could also do the calculation with maize-DDGS replacing Argentinean soybean meal (or soybean meal from any other country) and get other results of iLUC but this is not the point of this thesis.

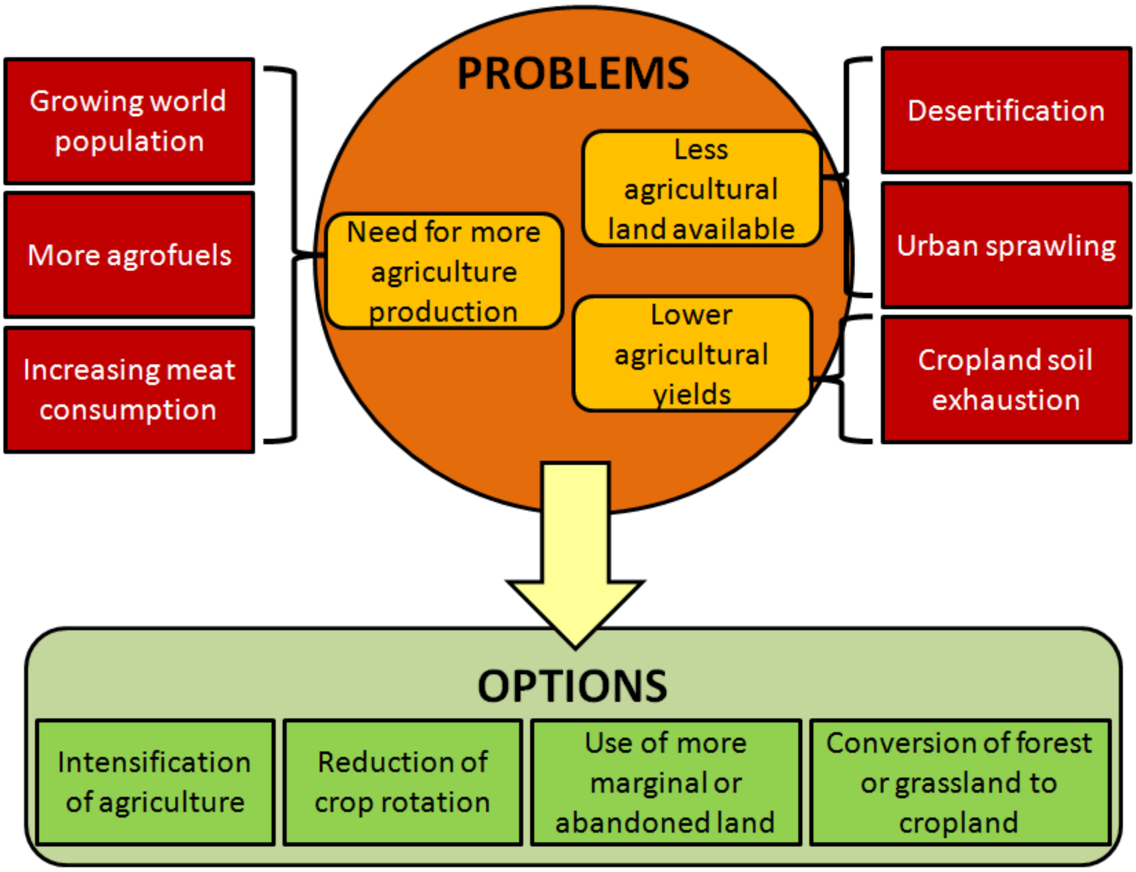
With simple calculations, it was shown that in a bottom-up approach, iLUC results can be very different depending on hypotheses such as:
- the type of crop that agrofuel by-products substitute for;
- the country where the crop that is substituted for by agrofuel by-products is grown;
- the country from where the original crop is displaced.

Moreover, these examples were only made for one type of agrofuel - ethanol from maize. Results would be very different for OSR agrodiesel for instance.

Since agriculture crop yields are higher in 'developed' countries, since most 'developed' countries are actively increasing the cultivation of feedstocks for agrofuel production and since LUC is limited due to existing regulations in 'developed' countries, it is expected that the production of feed/food will decrease in 'developed' countries, leading to a decrease in exports to and an increase in imports from 'developing' countries (DG Agri, 2007) and thus to indirect land use change in 'developing' countries (Searchinger *et al.*, 2008).

However, such approach does not take account of all the factors that can offset the need for more cropland due to the development of agrofuels such as the intensification of agriculture (that can lead to higher yields), the reduction of crop rotation and the use of more marginal or abandoned land. Finally, the increased pressure on cropland due to agrofuels can contribute to an increase in food prices and thus reduce the demand for food and for some types of land-intensive food such as meat (Gerbens-Leenes & Nonhebel, 2005).
The following diagram shows the different types of pressures on cropland and the ways these pressures are offset in today's agriculture if policies focus on supply rather than on demand mitigation options.

Figure 40: Pressures on cropland and supply-based mitigation options



Source: Personal diagram

As shown in this diagram, agrofuels are only one of many factors that put pressure on cropland while iLUC and LUC associated with agrofuels (conversion of forest, grassland or marginal/abandoned land to cropland) are only one of several ways to mitigate pressure on cropland. The environmental impacts of these options will be seen in 3.2.5, 3.2.6 and 3.2.7.

Thus, the bottom-up approach as described earlier looks insufficient in determining iLUC, which is often thought to require complex models and calculations usually performed in a top-down approach with numerous uncertainties (Al-Riffai *et al.*, 2010). However, as said by Bergsma about the cons from the GTAP model (one of the models used to determine iLUC), "people do not trust models" (Bergsma, 2008). Moreover, analysing such complex models is not the goal of this thesis which is more interested in showing the complexity of agrofuels' impacts and the poor understanding of these impacts.

3.2.4 iLUC is a global phenomenon

Some studies acknowledge that new sugarcane production in Brazil may replace pastures and food crops, which might move livestock and food crops to - for instance - the Cerrado which is an important ecosystem in terms of biodiversity and carbon storage (AEA Technology plc., 2008; Smeets *et al.*, 2008). However indirect land-use change is not a phenomenon restricted to tropical countries. iLUC is *per se* a global issue.

In the example of French OSR for agrodiesel production: when OSR is grown for agrodiesel production in France, 1 ha produces OSR oil (that is transesterified into RME) as well as rape seed meal (RSM) that can be used as a substitute of soybean meal from the US or from South America. Therefore, some production of soy in the US or in South America is not needed any longer ('positive' LUC).

However:
- if OSR was planted on this 1 ha before, there is a lack of rapeseed oil (which is displaced from food production) that needs to be compensated for either in the form of rapeseed oil or as a substitute to rapeseed oil depending on whether the former rapeseed oil was used for domestic consumption or for export. The main vegetable oils globally are soy oil and palm oil (FAO Statistics Division, 2009). So the displaced French rapeseed oil might be compensated by the marginal production of soy oil (from South America for instance) or the production of palm oil (from Malaysia or Indonesia) which generates 'negative' LUC.
- if OSR for agrodiesel production is planted at the expense of another crop, then there is a lack of this other crop that needs to be compensated for by the production of this other crop or by the

production of a substitute for this other crop, whether the former rapeseed oil was used for domestic consumption or for export. This other crop can come from any country depending on the type of crop that is displaced and generates 'negative' LUC.

The reality is more complex than above-mentioned but such examples enable to see that iLUC is a global phenomenon and cannot be restricted to the borders of one single country.

Cornelissen and Dehue chose several examples to illustrate the difficulty in assessing iLUC from agrofuels (Cornelissen & Dehue, 2009):

- "**Displacement effects act across national borders**: e.g. a shift in the oil palm produced in Malaysia from food to fuel could lead to an expansion of oil palm for food in Indonesia, with the accompanying risks of LUC;
- **Displacement effects act between substituting crops**: e.g. a shift in the rapeseed oil produced in the EU from food to fuel could lead to increased imports of a substituting vegetable oil, e.g. palm oil, for food. This puts additional pressure on oil palm expansion.
- **Competition for land connects also non-substituting crops**: e.g. high demand for maize may increase maize prices, leading to farmers planting more maize. This will mean less planting of another crop, e.g. soy. This could lead to an expansion of soy in other areas as a response to higher soy prices induced by the reduction in supply or additional pressures on soy-substituting crops."

This was clearly exemplified by Searchinger *et al.* who developed scenarios on the changes in the cropland of many countries due to the US ethanol programme (Appendix C of the Supporting Online Material) and found out that diverting maize from US cropland would in turn bring additional land into cultivation mainly in Brazil, China, India and the US (Searchinger *et al.*, 2008). Indeed, according to the FAO, the soybean acreage in the US fell by 16% in 2007/2008 compared with 2006/2007 - largely because farmers shifted land to maize (which is associated with the increase in maize agroethanol production) - which led to a substantial increase of the acreage of soybean in South America (GIEWS, 2008).

Similarly Edwards *et al.* acknowledge that "the largest increase in crop area resulting from either bioethanol or biodiesel expansion [for EU agrofuel mandates] would seem to be for soybeans in Brazil", but also palm oil in Malaysia and Indonesia and sugar cane in Brazil (Edwards *et al.*, 2008) while Banse *et al.* conclude from their modelling exercise that the EU agrofuel policy could have strong impacts on world agriculture and on global land use (Banse *et al.*, 2008).

3.2.5 iLUC GHG emissions

iLUC leads to potentially high GHG emissions, especially when forests are indirectly converted to croplands (cf. tables 3 and 4 in 3.1.3.3) in tropical countries or when peatlands are drained and burnt to leave place to cropland (leading to GHG emissions of 170 tonnes CO_2e/ha/y according to Edwards *et al.* (2008)).

However, there is no consensus on where agrofuels' iLUC actually occurs and on how much GHG emissions it produces. Once again, complex models try to predict where and how much forestland or pastureland is converted to arable land for agrofuel feedstock production (Dehue, 2009). This thesis does not aim at determining where iLUC occurs and how much GHG emissions iLUC produces but simply aims at underlining the complexity of the issue of agrofuels' impacts and the poor understanding of iLUC and its associated GHG emissions.

However, it should be noted that most now agree that iLUC GHG emissions would potentially negate all GHG savings from agrofuels (Edwards *et al.*, 2008).

Searchinger *et al.* were among the firsts to raise the issue of iLUC GHG emissions which had been largely ignored by then. They calculated that "US [maize]-based ethanol, instead of producing a 20% savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gases for 167 years". Similarly, Lapola *et al.* recently stated that "indirect land-use changes can overcome carbon savings from biofuels in Brazil" (Lapola *et al.*, 2010).

With all these uncertainties on iLUC and the fear that iLUC leads to large GHG emissions, one can easily understand why O'Hare said in an oral presentation that iLUC is the 'elephant in the room of biofuel policies' (O'Hare, 2009b).

3.2.6 Other environmental impacts associated with iLUC

Agrofuel feedstock production requires that new areas of land are put under cultivation. The marginal use of agricultural land to compensate for the loss of agricultural output due to the development of agrofuels causes numerous environmental impacts.

Edwards *et al.* call 'indirect annual emissions' the GHG emissions "due to fuel and fertiliser use as well as the change in nitrous oxide release from farm soils in the countries where the extra production will take place" (Edwards *et al.*, 2008). Actually, other environmental impacts similar to those described in 3.1.3.2 and 3.1.4.2 (case of conventional intensive agriculture) occur on farmland where extra production takes place because of agrofuels. They need to be taken into account as indirect impacts from agrofuel production but seem to be so far largely ignored or at least not accounted as consequences of agrofuels' development.

3.2.7 Non-iLUC indirect impacts from agrofuel development

As seen earlier, agrofuels' by-products play a part that should not be ignored in iLUC. Thus it is questionable whether impacts associated with agrofuel by-products are direct or indirect. Actually, it seems more appropriate to identify by-product impacts as **indirect** because the use of by-products is very distinct from the use of agrofuels.

Agrofuel by-products are often used as animal feed and are thus thought to replace otherwise produced animal feed. This induces lower iLUC estimates than when by-products are not taken into account. However, some of them are not directly available as animal feed and require processing before they are used as animal feed. For instance, maize ethanol production results in the production of WDGs (Wet Distiller Grains) that need to be dried to get DDGS. Such energy-intensive drying process is not needed in the case of maize or soybean that DDGS substitute for and is thus an indirect consequence of maize ethanol production that is however rarely mentioned. It sounds rational to consider that **energy use and GHG emissions associated with the drying process** (as well as GHG emissions due to sterilisation, packaging and shipping (Edwards *et al.*, 2007a)) are counted as indirect GHG emissions associated with by-products availability for their end use as animal feeds. Otherwise some agrofuel by-products get a GHG burden that considerably increases their GHG intensity and artificially benefits to agrofuel GHG intensity (Sadones, 2010).

Agrofuel by-products such as DDGS or rapeseed meal can also be seen as an **incentive for industry farming** since they contribute to practices where animals are separated from grasslands and fed with food they would not naturally eat. Moreover, it should be noted that an increase in maize DDGS (linked with maize ethanol production) in the diet of ruminants at the expense of maize might **increase methane emissions** (Behlke *et al.*, 2008).

iLUC could be avoided or reduced thanks to agriculture intensification. However, agriculture intensification can lead to practices that increase agriculture environmental impacts:
- more irrigation increases water stress and risks of salinisation;
- increased use of inputs (fertilisers, pesticides, etc.) can sometimes increase yields but also contribute to soil exhaustion as well as to an increase in numerous environmental impacts (cf. earlier);

- GMOs (for agrofuel feedstocks or for agricultural crops in general) are sometimes hailed as a way to increase yields and thus to reduce agrofuel iLUC (Calabotta, 2009; Darlington, 2009; Sheehan, 2009) but hindsight on GMOs does not seem sufficient to claim they bring more environmental benefits than what they may cost to the environment.

It should also be noted that agrofuels can be seen as **an incentive for oil consumption** and thus to **increased fossil carbon emissions** since they reduce the tension on oil demand and thus reduce its price compared to scenarios where agrofuels are not produced (Dixon *et al.*, 2007; Banse *et al.*, 2008).

However, an increase in food prices due to agrofuels' development could lead to a reduction of the demand for food or meat (O'Hare, 2009a) and thus reduce the environmental impact of global agriculture (including agriculture-related GHG emissions).

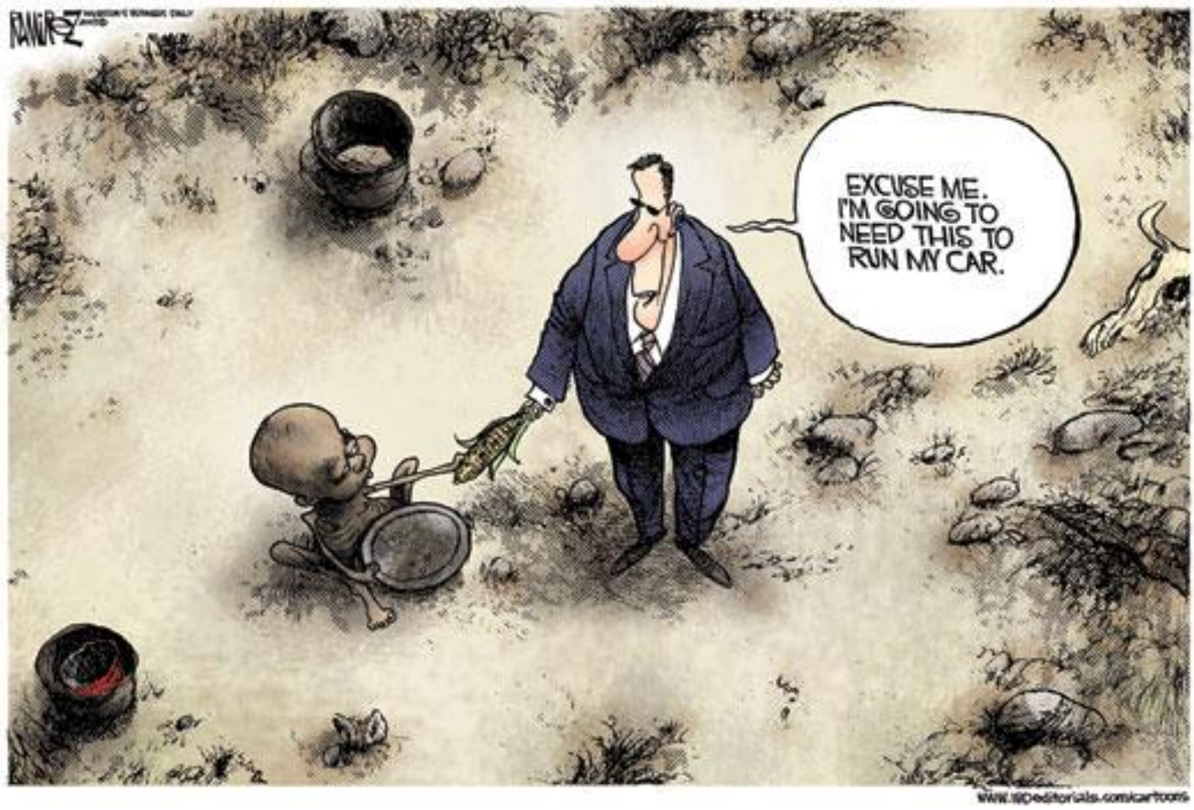
Finally, one can wonder whether producing agrofuels from biomass does not compete with other uses of land for bioenergy production. As other uses of biomass for bioenergy production could be more efficient GHG-wise than the use of agrofuels as energy sources, it could also be that in some cases, the use of agrofuels actually increases GHG emissions when compared to alternative uses of biomass with higher GHG efficiencies.

3.2.8 Food versus Fuel

The 'food versus fuel' debate is a very intense one in that some accused agrofuels of being a major cause for the 2008 hike in food prices (FAO, 2008a; b; Mitchell, 2008) while others saw agrofuels as having a minor responsibility in this increase (Abengoa Bioenergy, 2008; Pfuderer & del Castillo, 2008). Although we acknowledge that agrofuels potentially lead to an increase in food prices (the importance of which is subject to controversy), this social aspect was not examined in great detail for this thesis that focuses on environmental consequences of agrofuels. Lester Brown sees a competition between "the 800 million motorists who want to protect their mobility and the two billion poorest people in the world who simply want to survive" and reminds that filling a 25-gallon SUV (Sport Utility Vehicle) with maize ethanol requires the same amount of maize than that would feed one person for one year (Brown, 2006).

The following drawing is based on this idea of competition between (rich) motorists and already undernourished poor people.

Figure 41: Ironic cartoon showing the competition 'food versus fuel'



Source: from http://4.bp.blogspot.com/_kIAzAl2X2NM/SmzJQh4fZiI/AAAAAAAAA48/kuzV0hGLDuE/s1600-h/Cartoon+7.jpg

Jean Ziegler, special UN Rapporteur at the time on the right to food even said in 2007 that agrofuels were a "crime against humanity" for they would bring more hunger (Ferrett, 2007).

According to numerous papers, the influence of agrofuels is generally an increase in food prices (von Braun, 2007) not only because of an increase in the demand for specific crops (oilseeds for agrodiesel and cereals for agroethanol for instance) but also because sudden increased agrofuel demand contributed to the fact that crop utilisation was higher than crop production, which put pressure on stocks (GIEWS, 2008).

Several years after the surge in food prices the 'food versus fuel' is far from ended since agrofuel mandates for the next years will require more land for agrofuel production as well as more imports of feedstocks from 'developing' countries. Ironically, some countries that face hunger issues sometimes produce agrofuel feedstocks on lands that are owned by foreign investors (Rice, 2010). Such practices are sometimes qualified as 'land grabbing' and can look like a new form of colonialism (Cotula *et al.*, 2009).

Conclusion

It was shown in this chapter that the environmental impacts associated with agrofuels' production are numerous and diverse. **Agrofuels' production affects all environmental areas of concern, not only GHG emissions**. For the assessment of agrofuels' **direct** environmental impacts to be comprehensive, their '**secondary**' and '**tertiary**' environmental impacts (**which also affect numerous areas of concern**) also need to be taken into account (cf. 3.1.2.3).

Besides, the second part of this chapter stressed the importance of **indirect impacts**. iLUC associated GHG emissions are indeed thought by some to be large enough to overcome all expected GHG benefits from agrofuels. Unfortunately, iLUC is a complex notion that is somehow intangible and for which no definitive value can be given. Once again, it should be noted that agrofuels' **iLUC associated environmental impacts are not limited to GHG emissions but also affect all other environmental areas of concern** (cf. 3.2.6).

Finally, **indirect impacts are not limited to those associated to iLUC**. Other indirect impacts (**which again affect all environmental areas of concern**) are also related to agrofuels' production (cf. 3.2.7) and should thus be taken into account if a comprehensive environmental cost/benefit analysis of agrofuels is to be performed.

All these environmental impacts, whether they are direct (primary, secondary and tertiary) or indirect (related to iLUC or not), whether they are GHG emissions or affect other environmental areas of concern, need to be taken into account for a comprehensive understanding of agrofuels' overall environmental balance to be possible.

Such task is clearly extremely complex and there is thus a risk of oversimplification of agrofuels' environmental impacts, which may give a wrong idea of their net environmental balance. It seems that current scientific knowledge does not seem to be advanced enough to be able to precisely assess agrofuels' environmental implications.

Considering all these uncertainties, environmental certification may seem to some to be an interesting option in order to limit agrofuels' environmental impacts (Woods & Mercier, 2007). The interests and limitations of certifications will be discussed in the following chapter.

Chapter 4:
Certification does not make agrofuels sustainable

"The first step toward reducing our ecological impact is to recognize that the 'environmental crisis' is less an environmental and technical problem than it is a behavioural and social one. It can therefore be resolved only with the help of behavioural and social solutions. On a finite planet, at human carrying capacity, a society driven mainly by selfish individualism has all the potential for sustainability of a collection of angry scorpions in a bottle".

(Wackernagel & Rees, 1996), inventors of the concept of 'ecological footprint'

"Problems cannot be solved at the same level of awareness that created them."

Albert Einstein (1879-1955), Swiss-American scientist and philosopher

Introduction

Although agrofuels are often promoted on environmental grounds (cf. chapter 2), it was seen in chapter 3 that agrofuels' development nevertheless entailed numerous adverse environmental impacts, whether these impacts are direct or indirect.
In order to improve agrofuels' environmental balance, several organisations around the world developed initiatives (which will be called 'certification schemes' in this chapter) to ensure that certified agrofuels are produced while following environmental guidelines and thus have limited adverse consequences on the environment.

This fourth chapter aims at testing the following hypothesis: "current environmental certification schemes are stringent enough to make most agrofuels truly sustainable".

In a first instance, 'sustainability principles' and 'sustainability criteria' of selected certification schemes will be presented and compared. Since agrofuels are above all promoted for reducing GHG emissions compared with fossil fuels, a particular focus will be put on GHG emission reduction default values and on the comparison of the methodologies for calculating agrofuels' GHG emissions.
In a second instance, bias and uncertainties in agrofuels' GHG emission calculations will be identified and analysed.

Finally, some fundamental issues relating to 'better' agrofuels but also to any agrofuel in general will be identified and discussed, particularly shortcomings relating to the question of indirect land-use change (iLUC) and to the question of the evolution of transport energy demand at the world level. This will naturally lead to reflections on better ways to reduce GHG emissions, including behavioural changes that are thought to be needed.

Chapter objectives:

- Identify main initiatives addressing agrofuels' environmental impacts associated with agrofuel production;
- Make a comparison of selected initiatives and highlight the common points and differences;
- Compare the GHG emission reduction default values of different certification schemes;
- Make a comparison of GHG calculation methodologies;
- Bring out methodological bias and assumptions behind the differences in chosen GHG emission reduction default values;
- Identify some shortcomings of agrofuel certification schemes;
- Identify some "fundamental" challenges associated with agrofuels;
- Suggest ways to reduce agrofuel-related iLUC, including consumer-side solutions;
- Discuss the validity of the promotion of specific agrofuels on environmental grounds;
- Identify ways to make agrofuels less harmful to the environment;
- Identify ways to reduce transport GHG emissions more efficiently than by using agrofuels;
- Contextualise the share of agrofuels in transport and in total energy consumption at the world level.

4.1 A difficult comparison of agrofuels' certification schemes

Because of fears that agrofuels cause more environmental damage than they provide benefits regarding greenhouse gas emissions (cf. for example Doornbosch & Steenblik (2007)), numerous organizations have developed initiatives (called 'certification schemes' in this chapter) the goal of which is to ensure that the production of (certified) agrofuels has minimum negative impacts on the environment and does not result in a negative environmental balance.

This first section aims at presenting some of the main certification schemes and at comparing their set of 'sustainability' principles and criteria.

4.1.1 Why certify agrofuels?

Currently, numerous products need to comply with standards in terms of security/safety (for instance cars and toys) or health (food products, pollutant emission limits, etc.).

Until recently, similarly to fossil fuels from oil (fossil diesel and petrol), agrofuels consumed in Europe only needed to comply with standards relating to their physical specifications:
- EN 14214, which is the European standard that describes the requirements and test methods for Fatty Acid Methyl Esters (first-generation agrodiesel made with plant/animal oil that reacted with methanol)[29];
- EN 15376, which is the European standard that describes the requirements and test methods for agroethanol[30].

However, agrofuels are different from fossil fuels in that they are promoted for reducing GHG emissions compared with fossil fuels (cf. 1st and 2nd chapter of this thesis). Thus, one might expect more from agrofuels than mere compliance with physical specification standards. Indeed, since agrofuels are generally more expensive than the fossil fuels they substitute for (Kutas *et al.*, 2007; Steenblik, 2007), it is legitimate for customers or governments that buy or promote them to make sure that agrofuels at least deliver GHG benefits compared with fossil fuels. The first aim of agrofuel certification is thus to ensure that certified agrofuels at least deliver GHG benefits in comparison to fossil fuels.

But since agrofuels usually are a showcase of environment and transport policies, it also seems sensible that agrofuels are not produced at the expense of other environmental aspects.

The question of agrofuels' environmental benefits has been subject to high controversy for at least 5 years. Reports denouncing the destruction of parts of the South-East Asian or Amazon rainforest to grow palm oil trees or soybeans for agrodiesel production were published in as early as 2005 (Pearce, 2005). Then, the first major scientific articles claiming that some agrofuels had a negative energy balance (Patzek *et al.*, 2005; Pimentel & Patzek, 2005; Patzek, 2006) came out in 2005 and 2006 while a growing number of reports (Sourie *et al.*, 2005; Biofuelwatch, 2006; Sadones, 2006a), newspaper articles (for instance (Monbiot, 2005a; Monbiot, 2005b)) and journal articles (Hill *et al.*, 2006; Ho, 2006a) were increasingly negative about first-generation agrofuels. These publications totally contradicted the advertisements or communications from promoters of agrofuels and created turmoil within the publics of most Western countries.

[29] Cf. http://www.biofuels-platform.ch/en/infos/en14214.php
[30] Cf. http://www.biofuels-platform.ch/en/infos/en15376.php

Following the release in December 2005 of the EU Biomass Action Plan that reaffirmed the EU support for agrofuels (European Commission, 2005), the World Wildlife Fund (WWF) called for a “mandatory, legally binding, environmental certification” (WWF, 2006). Then, in 2007, several environmental NGOs launched a campaign asking the UK Government to introduce environmental criteria for agrofuels (cf. figure below).

Figure 42: 2007 NGO campaign asking the UK Government for environmentally certified agrofuels

Source: http://farm1.static.flickr.com/212/490445316_45be6fa96d.jpg

Due to intense controversy over the actual benefits of agrofuels for the environment, environmental certification schemes had to be rapidly developed and put in place to reassure the public as to the role of agrofuels in relation to the protection of the environment.

Rather disconcertingly, numerous subsequent reports and studies continued to cast a doubt on the interest of agrofuels for the environment (Doornbosch & Steenblik, 2007; Gilbertson *et al.*, 2007; JRC, 2007; Righelato & Spracklen, 2007; Crutzen *et al.*, 2008; Edwards *et al.*, 2008) and insisted for instance on the threat they could pose on biodiversity (Koh, 2007; Nellemann *et al.*, 2007; Reinhardt *et al.*, 2007) while agrofuels’ certification schemes were being developed at the same time.

On top of all these controversies about agrofuels' impacts on the environment, the increase in food prices between mid-2007 and 2008 was subsequently thought by many to be a consequence of the rapid development of agrofuels which were increasingly blamed for having some responsibility in the spike in food prices and for diverting crops from food production. For instance, Jean Ziegler, special UN Rapporteur at the time on the right to food said that biofuels were a "crime against humanity" for they would bring more hunger (Ferrett, 2007). This assertion was somehow implicitly confirmed by a 'secret note' from the World Bank (Mitchell, 2008) disclosed by the Guardian during the summer 2008, which blamed agrofuels for bearing the main responsibility in the food prices hike.

This point contributed to the inclusion of some social principles – particularly on competition between food and agrofuels – along with those already retained in agrofuel certification schemes.

Among all the controversies about agrofuels' environmental impacts, the issue of GHG emissions associated with indirect Land-Use Change (iLUC) raised in particular by Tim Searchinger (Searchinger *et al.*, 2008) is probably still today the main issue regarding the environmental balance of agrofuels. This very hot topic largely influenced certification schemes to have a closer look at indirect GHG emissions due to iLUC and even led several governments to reduce their agrofuel incorporation targets while the sustainability principles and criteria of several certification schemes have been modified several times particularly on the way iLUC GHG emissions were addressed.

4.1.2 Identification of the main environmental agrofuel certification schemes

The first papers that developed ideas on agrofuel environment certification probably arose in 2006 in Europe.

The EU launched in 2006 a public consultation on agrofuels asking respondents their views on a potential certification scheme (European Commission, 2006). In the meantime several organizations started to propose environmental criteria and guidelines that would need to be followed for agrofuel feedstock cultivation and agrofuel production to minimize environmental risks (Cramer *et al.*, 2006; ECCM *et al.*, 2006; EEA, 2006; Fritsche *et al.*, 2006). Several academic studies also aimed at facilitating the creation of new certification schemes for agrofuels (Lewandowski & Faaij, 2006; Pelvin, 2006). The initial work on 'sustainability principles' was completed with methodologies for agrofuels GHG emission calculations

(Bauen, 2007; Bergsma *et al.*, 2007) and updates on the certification schemes (Cramer *et al.*, 2007; Dehue *et al.*, 2007a).

The UK Government that had been working since 2005 on the coming new transport regulation called RTFO (Renewable Transport Fuel Obligation) issued a draft recommendation to the RTFO administration on 'Carbon and Sustainability Reporting' in June 2007 (DfT, 2007). Meanwhile the German Government also proposed a list of 'sustainability criteria' for agrofuels for its coming Biomass Sustainability Ordinance (BSO – or BioNachV in German for *Biomasse-Nachhaltigkeits-Verordnung*) (German Government, 2007).

The UK RTFO eventually came into force on 15th April 2008 with targets for agrofuel incorporation, a proposed 'sustainability' meta-standard and a GHG calculator accompanied with default GHG values for the main fuel chains.

Finally, the European Commission released a proposal for a Directive on Renewable Energy Sources in January 2008 (European Commission, 2008) and eventually published the resulting Directive in April 2009 (European Commission, 2009d) after numerous negotiations and changes. This Directive includes 'sustainability criteria' (cf. tables 9 to 17) for agrofuels as well as default values and methodologies for the calculation of GHG emissions from main agrofuel chains.

To comply with the new EU Directive, the RTFO recently had to adapt its scheme to make it 'RED-ready' (RFA, 2010a) while the German Government updated its BioNachV (Biomass Sustainability Ordinance) (German Government, 2007)[31] and published the new BioSt-NachV (for *Biomassestrom-Nachhaltigkeitsverordnung*, or 'Biomass-Electricity Sustainability Ordinance') (German Government, 2009) in 2009. In parallel, work on agrofuels' certification was performed in the US, at the federal level (Renewable Fuels Standard RFS developed by the US EPA - Environment Protection Agency) and at the state level especially in California (Low Carbon Fuel Standard LCFS).

In fact, numerous other initiatives worldwide have developed sets of criteria for the certification of agrofuels all along their production chain or only for the cultivation of specific agrofuel crops (Ismail & Rossi, 2010).

[31] This document can be found in English at the following address: http://www.sea-cr.com/Data%20for%20website/B2%20renew%20energy%20sec/Renewable/German%20Biofuels%20Sustainability%20Ordinance%20%282008%29.pdf

The following are examples of initiatives that focus on the certification of the cultivation of the agrofuel feedstock:

- the Better Sugarcane Initiative (BSI) is intended for the certification of sugarcane cultivation and can thus be seen as a certification of the cultivation part for sugarcane agroethanol while the SEKAB Verified Sustainable Ethanol Initiative proposes criteria for Brazilian ethanol from sugar cane sold in Sweden;
- the Roundtable for Sustainable Palm Oil (RSPO) aims at certifying ‘sustainable’ oil from palm trees and thus includes criteria for agrodiesel from palm oil;
- the RoundTable for Responsible Soy (RTRS) and the Basel Criteria for Responsible Soy Production have criteria for soy cultivation and could thus be used as a certification scheme for the cultivation part of the production of agrodiesel from soybean;
- the Brazilian Social Fuel Seal aims at certifying agrodiesel from Brazil (it is mostly a social certification).

However, it was thought more constructive to only make a comparison of schemes that are capable of certifying any agrofuel. Therefore, it was decided in this study to focus on the following six certification schemes:

- the theoretical scheme developed by the ‘**Cramer Commission**’ (under SenterNovem lead) in the Netherlands (Cramer *et al.*, 2006; Bergsma *et al.*, 2007; Cramer *et al.*, 2007), as a response to the Dutch Government intention to incorporate sustainability criteria for biomass in relevant policy instruments;
- the theoretical scheme developed by the Öko-Institut for **WWF Germany** (Fritsche *et al.*, 2006);
- the legal scheme developed by Ecofys and E4Tech (ECCM *et al.*, 2006; Bauen, 2007; Dehue *et al.*, 2007a; DfT, 2007; E4Tech, 2007; DfT, 2008; RFA, 2008a) for the Renewable Fuels Agency (**RFA**), which has been the agency in charge of implementing the RTFO (Renewable Transport Fuel Obligation) since April 2008 for the UK Government;
- the legal scheme developed by UC (University of California) Berkeley and UC Davis for the implementation of a Low Carbon Fuel Standard (**LCFS**) in California (Farrell & Sperling, 2007a; b);
- the voluntary scheme developed by the Roundtable on Sustainable Biofuels (**RSB**) hosted by *Ecole Polytechnique Fédérale de Lausanne* (EPFL, Switzerland) (Roundtable on Sustainable Biofuels, 2007a; 2008; 2009; 2010);
- the scheme developed by the **European Commission**, which released in January 2008 a draft proposal for a “Directive on the promotion of the use of energy from renewable sources” (European Commission, 2008) and eventually the final Directive - called ‘Renewable Energy Directive’ or RED - in April 2009 (European Commission, 2009a).

It should be noted that during the course of this research, some of the certification schemes largely evolved compared to their initial positions. For instance, the UK RTFO was recently largely modified in order to comply with the EU RED (RFA, 2010a; b). Thus some of the RTFO ambitions were watered down so that they do not go beyond the European requirements. Besides, the RSB that aimed at including indirect GHG emissions from iLUC (though only theoretically because there was no methodology for their calculation) in its 2007 draft principles (Roundtable on Sustainable Biofuels, 2007a) finally decided not to include them in its 2009 Version 1.0 (Roundtable on Sustainable Biofuels, 2009). Finally, the Californian LCFS which originally contained drafts of 'sustainability criteria' but no methodology on iLUC GHG emission integration, was subsequently modified to include a methodology to take account of indirect land-use change while the development of other environmental criteria has been postponed (Air Resources Board, 2009; State of California, 2010).

It was decided to compare certification principles and criteria of the latest papers as of early 2008 (apart from the RED - published in April 2009 - which is very similar to the 2008 Directive proposal apart for the choice of some GHG emission default values – a point that will be developed in section 4.1.4) because after the publication of the draft of the European Directive in January 2008, several organisations (such as those working on the RTFO, the Dutch and the German schemes) understood they would sooner or later have to comply with the forthcoming legally binding EU Directive (which eventually came out in April 2009) and thus did not continue their work on agrofuel certification. Moreover, the state of the 2007 work on the LCFS included certification criteria, which is not the case any longer (at least until December 2011) (Air Resources Board, 2009).

Thus, the papers on which the following tables are based and that were used as basis for the comparison of agrofuel certification schemes are the following:

- "Testing framework for sustainable biomass" (Cramer *et al.*, 2007);
- "Sustainability standards for bioenergy" (Fritsche *et al.*, 2006);
- "Carbon and Sustainability Reporting Within the Renewable Transport Fuel Obligation - Technical Guidance v1.1" (RFA, 2008a);
- "A Low-Carbon Fuel Standard for California - Part 2: Policy Analysis" (Farrell & Sperling, 2007b);
- "Global principles for sustainable biofuels production (2nd version) - October 23rd, 2007" (Roundtable on Sustainable Biofuels, 2007b);
- "Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC" (European Commission, 2009a), especially the article 17 of this Directive.

4.1.3 Comparison of the principles and criteria of selected certification schemes

The objective of this section is to compare the 'sustainability' principles and criteria of selected agrofuel certification schemes.

Certification schemes aim at setting a context and guidelines that – if followed by 'certified agrofuels' – ensure that such agrofuels have less negative impacts on the environment (and people for schemes that include social criteria) than if no certification is put in place.

Most schemes use the terminology 'sustainability principles and criteria', which implicitly means that agrofuels meeting their principles and criteria would be sustainable (this is somehow explicit in the case of the Roundtable for *Sustainable* Biofuels). We will see further in this chapter whether such a vision is sensible.

Our analysis of agrofuels' certification schemes brings out the point that in order for certification schemes to encompass most environmental and social impacts of agrofuels, principles and criteria can be divided into 8 main categories or 'areas of concern', which are listed in the table below:

Table 8: Social and environmental areas of concern associated with agrofuel production

Direct GHG emissions	iLUC
Biodiversity	Soil
Water	Air
Socio-economic issues	Competition with other uses of biomass

Source: Personal table

Some schemes have not developed social criteria (those related to the areas of concern called 'socio-economic issues' and 'competition with other uses of biomass' – which includes competition with food) but all selected schemes have at least mentioned draft criteria for all of the above-listed environmental areas of concern.

A ninth area of concern that could be called 'other indirect environmental impacts' (whose impacts are mentioned as 'non-iLUC indirect impacts in section 3.2.7 of chapter 3) could have been added to the table above, however, none of the schemes analysed have developed criteria nor even mentioned this area of concern. Thus, so far, the only indirect impacts that are (sometimes) taken into account in agrofuels' certification schemes are GHG emissions due to iLUC, while those described in section 3.2.7 of chapter 3 are ignored.

The aim of this section is not to review and compare all the points of the selected initiatives in detail. Some comparisons of several schemes have already been done - although in a different way - by several authors (Dehue *et al.*, 2007b; Chalmers, 2008; van Dam *et al.*, 2008; Ismail & Rossi, 2010). However, it was thought interesting to classify similar criteria from the different certification schemes into clear separate tables, allowing an easier comparison.

The 8 following tables (tables 9 to 17) were made in order to classify 'sustainability criteria' of the schemes mentioned at the end of the former section according to the areas of concerns identified in table 8:

Table 9: GHG emissions criteria

GHG EMISSIONS					
Cramer (NL)	**WWF Germany**	**RFA (UK)**	**LCFS (CA)**	**RSB (Swiss)**	**EC**
❑ **GHG emission savings:** - at least **30%** GHG reduction compared to fossil fuels but policy instruments should promote higher percentages of GHG emission reduction ❑ **High carbon stock land:** - no installation of new biomass production units (BPUs) in areas in which the loss of above-ground carbon storage cannot be recovered within a period of 10 year of biomass production or with a great risk of significant carbon losses from the soil (e.g. certain grasslands, peat areas, mangroves and wet areas…). Reference date = 1st January 2007, except for already certified BPUs	❑ **GHG emission savings:** - demonstration of a maximum 30 $kgCO_2e/GJ$ life-cycle GHG balance of bioenergy cultivation (lower heating value of the bioenergy delivered at the field including all inputs, direct emissions from fertilizer application, potential soil carbon release and no crediting for by-products) which represents a **67%** reduction on the life-cycle GHG emissions from unprocessed crude-oil combustion - demonstration of a minimum 67% conversion efficiency in the processing of bioenergy crops, taking into account by-products for which proof of use is given. Maximum direct GHG emission factor for the process energy = 60 $kgCO_2e/GJ$	❑ **GHG emission savings:** - non-compulsory targets for fuel suppliers of **40%** GHG emission savings in 2008-2009, **45%** in 2009-2010 and **50%** in 2010-2011 ❑ **High carbon stock land:** - no BPU for which biomass production causes direct land use change with a carbon payback time exceeding 10 years (reference date = 30th November 2005) - no BPU on soils with a large risk of significant soil stored carbon losses such as peat lands, mangroves, wetlands and certain grasslands (reference date = 30th November 2005)	❑ **GHG emission savings:** - **10%** decrease in carbon intensity (in gCO_2e/MJ) of transportation fuels in California by 2020 - mandatory reporting and labelling of carbon intensity of transportation fuels	❑ **GHG emission savings:** - reduction of GHG emissions compared to fossil fuels on a life cycle basis including direct and indirect GHG emissions, land-use change and displacement	❑ **GHG emission savings:** - at least **35%** GHG emission savings (50% from 2017 and 60% from 2018 for biofuels produced in installations that started after 1st January 2017). For installations that were in operation on 23rd January 2008, the 35% obligation applies only from 1st April 2013. - reporting from Member States (MS) on the **estimated** net GHG savings due to biofuel use - contribution made by biofuels from waste, residues, non-food cellulosic material and ligno-cellulosic material considered twice that made by other biofuels ❑ **High carbon stock land:** - no biofuel raw material from land with high carbon stock, i.e. lands that are wetlands or continuously forested areas in January 2008

Table 10: GHG emission calculation methodologies

GHG EMISSIONS CALCULATION METHODOLOGIES					
Cramer (NL)	**WWF Germany**	**RFA (UK)**	**LCFS (CA)**	**RSB (Swiss)**	**EC**
❑ **Fertilisers:** - Default value for GHG emissions due to fertiliser production and N-fertiliser application to be discussed with experts - use of phosphate and potash fertiliser not taken into account ❑ **Land-use change:** - land-use change emissions default factors according to IPCC, annualised according to relevant lifetimes to be determined ❑ **Co-products:** - preferred use of system extension (**substitution**) with allocation of co-product according to relevant market but other possible allocations to be discussed - residue reference included in GHG calculation	❑ **GHG calculation methodology** - no methodology - due to a broad range of GHG balances for biofuels, more research is needed to determine credible ways to measure GHG balances - need for a simplified approach to GHG accounting to avoid excessive compliance costs ❑ **Fertilisers:** - accounting of GHG emissions from input of fertiliser and fertiliser emissions ❑ **Land-use change:** - accounting of changes in carbon stocks from land use change ❑ **Co-products:** - use of **system extension** to calculate conversion efficiency only, with effective use of by-product	❑ **Fertilisers:** - emission factors provided for fertilisers ❑ **Land-use change:** - default values of land use change impacts on GHG emissions calculated according to IPCC guidelines and annualised over a 20 year period ❑ **Co-products:** - **substitution** approach preferred but also use of various allocation methods depending on co-products - reference for residues = left on the field, with no GHG impact apart from palm oil residues assumed to provide heat and power	❑ **GHG calculation methodology:** - no methodology yet	❑ **GHG calculation methodology:** - no methodology yet	❑ **GHG calculation methodology:** - use of a set default value, a value resulting from the sum of actual values and disaggregated default values, or an actual value calculated in accordance with the methodology ❑ **Land-use change:** - default values of land use change impacts on GHG emissions annualised over a 20 year period ❑ **Co-products:** - use of **energy allocation** for the GHG emission calculation but reporting from the European Commission also with the substitution approach

Table 11: Criteria about iLUC and GHG emissions due to iLUC

ILUC					
Cramer (NL)	**WWF Germany**	**RFA (UK)**	**LCFS (CA)**	**RSB (Swiss)**	**EC**
❑ **GHG emissions from displacement:** - *recommended that displacement is monitored at the macro scale* ❑ **Displacement:** - information on changed land use (inclusive of future development if information is available) - monitoring of the shifts in land use and vegetation	❑ **GHG emissions from displacement:** - not taken into account ❑ **Displacement** - bioenergy crop development concentrated on available arable land in the case of effective land-use policies in the given country; otherwise, bioenergy crop development restricted to areas not in competition with other uses	❑ **GHG emissions from displacement:** - not taken into account - notion of "idle land" that gets round displacement ❑ **Displacement** - RFA to report on land use change arising as an indirect result of biofuel production	❑ **GHG emissions from displacement:** - "**a non-zero estimate** of the global warming impact of indirect land-use change for crop-based fuels should be developed" (no methodology though)	❑ **GHG emissions from displacement:** - indirect GHG emissions and displacement **taken into account** (no methodology though) - GHG emissions from iLUC should be minimized	❑ **GHG emissions from displacement:** - not taken into account ❑ **Displacement:** - monitoring by the EC of the impacts of biofuel production on land use in the country of supply - reporting from the MS on land-use changes within the MS associated with its increased use of biomass ❑ **Environmental impacts:** - reporting from the EC on the impact of increased demand for biofuel on sustainability in exporting countries

Table 12: Biodiversity criteria

BIODIVERSITY					
Cramer (NL)	**WWF Germany**	**RFA (UK)**	**LCFS (CA)**	**RSB (Swiss)**	**EC**
❑ **Protected areas**: - no biomass production in recently cultivated “gazetted” areas, high-conservation value (HCV) areas or within a 5 km zone around these areas, unless protection of biodiversity values is part of the management ❑ **Biodiversity management:** If biomass production is taking place in recently cultivated areas (after 1st January 2007): - at least 10% room must be set-aside - indication on the BPU’s type of land zone, how fragmentation is discouraged, if ecological corridors are applied and if the restoration of degraded areas is involved - need to apply good practices on and around the BPU for the strengthening of biodiversity	❑ **Protected areas**: - no BPU on high-nature-value areas, buffer zones and migration corridors ❑ **Biodiversity management:** - maintain buffer zones for habitats of endangered species - protection of high-nature-value farming systems - genetic biodiversity preserved within the bioenergy cropping area - need for a fire protection strategy ❑ **Biotechnology**: - no GMO as bioenergy crops ❑ **Biosecurity** - no alien species cultivated unless careful control and monitoring	❑ **Protected areas**: - no BPU in gazetted areas, HCV areas and areas of high biodiversity ❑ **Biodiversity management:** - documentation on endangered species and high conservation value habitats in and around the production site - need for a biodiversity management plan to avoid disturbance of the endangered species and habitats - *recommendation to preserve the surrounding landscape*	❑ **Protected areas**: - *recommendation of no biofuel production on certain types of lands (e.g. old growth forest, national and state parks and other protected lands)* ❑ **Biodiversity management:** - *recommendation for a reporting requirement on the loss of wilderness and natural habitats* ❑ **Biotechnology**: - *recommendation for a reporting requirement on the use of GMO*	❑ **Protected areas**: - avoid negative impacts on biodiversity and areas of high conservation value ❑ **Biotechnology**: - no biotechnology used unless it improves social and/or environmental performances of biofuels, in compliance with national or international biosafety and transparency protocols ❑ **Biosecurity** *(principle not validated yet)*: - no introduction of invasive species - evaluation of biofuel feedstocks for risk of biological invasion - entire responsibility of producers when risks exist	❑ **Protected areas**: - no biofuels from lands with high biodiversity value, i.e. lands that are forests undisturbed by significant human activity, areas designated for nature protection purposes or highly biodiverse grassland in January 2008 - reporting from MS on the estimated impact of biofuel production on biodiversity

Table 13: Soil criteria

SOIL					
Cramer (NL)	**WWF Germany**	**RFA (UK)**	**LCFS (CA)**	**RSB**	**EC**
❑ **Soil erosion:** - need for a strategy aimed at the prevention and control of erosion ❑ **SOM and nutrient balance:** - need for a strategy aimed at the conservation of nutrient balance and organic matter in the soil - no use of agrarian residual products at the expense of the maintenance of the soil and soil quality ❑ **Salinisation:** - need for a strategy aimed at the prevention of soil salinisation ❑ **Agrochemicals:** - compliance with the Stockholm Convention when national legislation is lacking	❑ **Soil erosion**: - exclusion or significant reduction of bioenergy crops requiring intense tilling and below-surface harvesting (e.g. sugar beets) - maximum soil-specific slope limits for bioenergy crop cultivation - use of farming and harvesting practices that reduce erosion risks and adverse soil compaction (irrigation schemes, harvesting equipments) ❑ **SOM and nutrient balance:** - maximum extraction rates for agricultural and forestry residues (specific for soil and crop/crop rotation) - acceptable removal levels for agro-and forestry residues, so that humus and organic C soil content is not negatively affected ❑ **Salinisation:** - irrigation schemes to prevent salinisation - exclusion of crops and cropping systems for which such schemes are not applicable (specific to soil type and semi-dry/dry regions) ❑ **Agrochemicals:** - need for a qualitative standard on the toxicity and biodegradability of agrochemicals - preference for non-chemical pest treatments and organic fertilisers	❑ **Soil erosion**: - need for a soil management plan aimed at sustainable soil management, erosion prevention and erosion control - annual documentation of good agricultural practices regarding prevention and control of erosion, maintaining and improving of soil structure ❑ **SOM and nutrient balance:** - annual documentation of applied good agricultural practices regarding soil nutrient balance, soil organic matter (SOM), pH and biodiversity - *recommendation to record annual soil losses, N-P-K balance, SOM and pH in top soil* - *recommended that no by-product is used at the expense of the soil nutrient or the SOM balance, neither at the expense of important traditional uses (e.g. fodder, natural fertiliser) unless better alternatives are available and applied* ❑ **Salinisation:** - annual documentation of applied good agricultural practices regarding the prevention of salinisation - *recommendation to record annual soil salts content* ❑ **Agrochemicals:** - compliance with the Stockholm Convention	❑ **Soil erosion**: - *recommendation for a reporting requirement on soil erosion*	❑ **Soil quality**: - no direct or indirect damaging or degradation of soils	❑ **Soil quality**: - reporting from MS on the estimated impact of biofuel production on soil quality

Table 14: Water criteria

WATER					
Cramer (NL)	**WWF Germany**	**RFA (UK)**	**LCFS (CA)**	**RSB (Swiss)**	**EC**
❑ **Water quantity**: - need for a strategy aimed at sustainable water management with regard to an efficient use of water - no water from non-renewable sources for irrigation and the processing industry ❑ **Water quality:** - need for a strategy aimed at sustainable water management with regard to a responsible use of agrochemicals	❑ **Water quantity**: - use of optimised farming systems requiring low water input, e.g. agro-forestry systems in dry regions - avoid critical irrigation needs in semi-dry and dry regions by applying water-management plans to provide a sustainable and efficient water supply for irrigation ❑ **Water quality:** - maintain the quality and availability of surface and ground water, avoid the negative impacts of agrochemicals (by timing and quantity of application) - no untreated sewage water for irrigation - the agricultural management plan must include the re-use of treated waste-water	❑ **Water quantity**: - need for a plan aimed at sustainable water use - annual documentation of applied good practices with respect to efficient water usage - *recommendation for annual measurements of water sources used (l/ha/y)* ❑ **Water quality:** - need for a plan aimed at the prevention of water pollution - annual documentation of applied good practices with respect to responsible use of agro-chemicals and waste discharge - *recommendation for annual measurement of agrochemical inputs and BOD (Biological Oxygen Demand) level in and around the BPU*	❑ **Water quality**: - *recommendation for a reporting requirement on water quality*	❑ **Water quantity**: - no direct or indirect depletion of water resources ❑ **Water quality:** - no direct or indirect contamination of water resources	❑ **Water quantity and quality :** - reporting from MS on the estimated impact of biofuel production on water resources - avoidance of excessive water consumption in areas where water is scarce ❑ **Water quality:** - reporting from MS on the estimated impact of biofuel production on water quality

Table 15: Air criteria

AIR					
Cramer (NL)	**WWF Germany**	**RFA (UK)**	**LCFS (CA)**	**RSB (Swiss)**	**EC**
❑ **Air quality**: - need for a strategy aimed at minimum air emissions (during the production and the processing, as well as from waste) ❑ **Burning:** - no burning in the installation or the management of the BPU, except in specific situations (such as described in ASEAN - Association of South East Asian Nations - guidelines on zero burning)	❑ **Burning**: - no use of fire to prepare or clear land unless preferred ecological option	❑ **Burning**: - no burning for land clearing or waste disposal, except in specific situations (such as described in ASEAN guidelines on zero burning)	❑ **Air quality**: - *recommendation for a reporting requirement on air quality*	❑ **Air quality**: - no direct or indirect air pollution	❑ **Air quality**: - Report by the EC on national measures taken to respect air protection

Table 16: Criteria about socio-economic issues

SOCIO-ECONOMIC ISSUES					
Cramer (NL)	**WWF Germany**	**RFA (UK)**	**LCFS (CA)**	**RSB (Swiss)**	**EC**
❑ **Local impacts**: - need to describe the direct economic value that is created, the budget spent on local supply companies - no land use without the informed consent of original users - official description of land use and description of practices - respect of customary laws of the indigenous population - monitoring of property structures (exclusion of small producers from land ownership?) ❑ **Workers**: - need to describe the procedure of appointment of local staff and the share of local senior management - compliance with ILO (International Labour Organization) and UN Human Rights - description of measures dealing with corruption	❑ **Local impacts:** - clarification of land ownership and land-tenure - no exclusion of poor people from the land ❑ **Workers**: - compliance with ILO standards on workers' safety, rights (including occupational-health impacts), wage policies, child labour, seasonal workers' conditions and working hours during harvest time - necessity to include a standard on income distribution and poverty reduction - prevention of accidents	❑ **Local impacts:** - demonstration of the right to use the land - evidence of no diminution of legal or customary rights of other users - *recommended that no by-product is used at the expense of important traditional uses (e.g. material, local fuel) unless better alternatives are available and applied* ❑ **Workers**: - workers informed about their rights - rights for workers to negotiate their working conditions without discrimination - no labour for children under 15 unless on family farm if workday less than 10 hours - no hazardous or dangerous work for youth workers (15-17) - health and safety training provided when appropriate - wages at least equivalent to legal national minimum or the relevant industry standard (whichever is higher)	❑ **Local impacts:** - *recommendation for a reporting requirement on the concentration of land holdings and land appropriation* ❑ **Workers:** - *recommendation for a reporting requirement on worker safety*	❑ **Local impacts:** - no violation of land or water rights - contribution to social and economic development of local, rural and indigenous peoples and communities ❑ **Workers:** - no violation of human rights or labour rights - ensure decent work and well-being for workers	

Table 17: Criteria about competition with other uses of biomass

COMPETITION WITH OTHER USES OF BIOMASS					
Cramer (NL)	**WWF Germany**	**RFA (UK)**	**LCFS (CA)**	**RSB (Swiss)**	**EC**
❑ **Competition with other uses:** - information on changes in prices of land and prices of food for producers and consumers (inclusive of future development if information is available) - mapping of food security	❑ **Competition with other uses:** - no cultivation of bioenergy crops at the disadvantage of food crops (food security) - need for a regional risk assessment which analyses the potential impacts of biomass production on the local and regional food supply	❑ **Competition with other uses:** - RFA to report impacts of biofuels on food and other commodity prices	❑ **Competition with other uses:** - *recommendation for a reporting requirement on food prices*	❑ **Competition with other uses:** - no deterioration of food security	❑ **Competition with other uses:** - reporting from the MS on commodity price within the MS associated with its increased use of biomass - reporting from the EC on the impact of increased demand for biofuel on availability of foodstuffs in exporting countries, ability of people in 'developing' countries to afford these foodstuffs and wider development issues and the impact on biomass using sectors

This thesis focuses on GHG emissions because GHG emission reductions expected from agrofuels are one of the main arguments for the promotion of agrofuels today. Thus, despite the acknowledged importance of criteria regarding other environmental aspects than GHG emissions, more stress has been placed upon GHG emission criteria and GHG methodologies for agrofuel certification schemes.

Regarding GHG emissions criteria, some of the main points arising from the comparison of the tables above - and that will be discussed in section 2 of this chapter - are the following:

- the targets for GHG emission reductions are very different depending on the certification schemes;
- the dates retained for when direct land-use change is not permitted on high-carbon stock land or highly biodiverse areas range between 2005 and 2008. It is surprising that no earlier reference date is found in these certification schemes insofar as deforestation and LUC have been negatively publicised for decades. The choice of such recent reference dates may be implicitly seen as an approval of LUC that happened until 2005 or 2008.
- GHG emissions from LUC are annualised over 20 years for the EC and the RFA schemes, but the Cramer commission raised the issue that a relevant lifetime needed to be determined for LUC annualisation;
- the substitution approach (or system expansion) is the co-product treatment method that is used by all schemes with a GHG emission calculation methodology, apart from the European Commission, that chooses the energy allocation procedure (cf. a detailed discussion of this point in section 4.2.2);
- although they might be the main issue about agrofuels' GHG balance, potentially making agrofuels more GHG intensive than fossil fuels, iLUC GHG emissions are ignored in most schemes, except in the RSB and LCFS where they are only theoretically taken into account.

<u>Nota Bene on the inclusion of iLUC in agrofuel GHG emission calculation methodologies</u>:
Further to the 2007 RSB paper used for these tables, the RSB eventually decided not to deal with iLUC GHG emissions and leave this question to governments (Roundtable on Sustainable Biofuels, 2008).

As to the Californian LCFS, models were developed by the Energy & Resource Group (at the University of California Berkeley) from early 2008 in order to include iLUC in agrofuels' GHG emissions (Farrell & O'Hare, 2008). However, since then, agrofuel proponents have several times fiercely asked that iLUC GHG emissions are not taken into account in the LCFS agrofuel GHG emission calculation methodology. For instance, an open letter by experts favourable to agrofuels was sent to the California Air Resource Board (in charge of developing the LCFS) on 24th June 2008 to ask for the LCFS not to be based in regards of indirect impacts of agrofuels, thought to be lacking sufficient empirical data (Simmons *et al.*, 2008). Then in 2009, maize agroethanol proponents blamed the proposed LCFS regulation for including iLUC GHG emissions thought to be relying on unproven science (ClimateBiz Staff, 2009). Finally, the scheme was attacked for discriminating against US maize ethanol (Power, 2009). With this context in mind, the death (suicide?) on 13th April 2008 of Alex Farrell, lead author of the LCFS reports used for the above tables, raises questions as to the potential pressures he may have experienced while working on the development of agrofuels' iLUC GHG emissions methodologies for the LCFS (Romm, 2008).

Similarly, in early 2009, the EPA (US Environmental Protection Agency) had published draft studies indicating the need to include agrofuels' iLUC GHG emissions in the revision of the Renewable Fuel Standard RFS (ICF International, 2009; Office of Transportation and Air Quality, 2009). However, a Bill that passed at the US House of Representatives in June 2009 asked the EPA not to take account of international iLUC for 5 years (Lane, 2009). Eventually, the Obama Administration decided to rule out the inclusion of iLUC GHG emissions from the revised RFS in February 2010, following intense lobbying from the maize agroethanol industry (Winter, 2010). Moreover, recently updated figures showed surprisingly favourable for maize agroethanol GHG emissions (Harte, 2010). This was justified by the EPA which simply stated that it "used the best available models […], and incorporated many modifications to its proposed approach based on comments from the public, a formal peer review, and developing science" (Office of Transportation and Air Quality, 2010).

These two situations regarding the inclusion of iLUC GHG emissions in agrofuel GHG emission calculation methodologies clearly show that iLUC is a point of major controversy as it may prevent the interests of some agrofuel producers from moving forward if iLUC is taken into account in policies and legislations that favour agrofuels with low GHG emissions (at least lower than those of fossil fuels).

Besides, several points are thought worth mentioning regarding areas of concern other than GHG emissions:

- only the WWF has a criterion asking for GMOs (Genetically Modified Organism) not to be used as bioenergy crops. Then the RSB opposes GMOs unless they prove beneficial. Such little mention of GMOs in environmental certification schemes is surprising since GMOs are a controversial technology (cf. 4.3.2.3);
- some schemes seem to have gone into more detail and stringency than others, by proposing criteria on invasive species, soil organic matter, soil nutrient balance and soil salinisation;
- the most stringent criterion about soil is the one from the WWF, which requires a decrease in the use of crops requiring intense tilling or below-surface harvesting in order to reduce risks of

soil erosion. The WWF even suggests that sugar beet is not a certifiable agrofuel feedstock because of the extensive impacts its cultivation has on soil. No other scheme excludes specific crops from being certifiable agrofuel crops;
- only the EC Directive has no criteria regarding socio-economic issues.

Actually, the main conclusion one can draw from the comparison of these tables is that apart from GHG emission reduction targets, the criteria look relatively similar at first sight, apart from those developed by WWF, whose certification scheme seems to have the most ambition since it has numerous stringent criteria not only regarding GHG emission reductions but also regarding all other environmental and social aspects. Other schemes, especially those ignoring iLUC GHG emissions seem to have much more modest ambition.

4.1.4 Question of the stringency of certification schemes

The "certification" process provides that a certified product has theoretically met standards set by the certification body but says nothing about the stringency of the standards. Indeed, when agrofuels bear the claim 'certified', this can make consumers believe that such agrofuels are 'sustainable' (especially if the certification body is called 'Roundtable for *Sustainable* Biofuels' for instance), and have very limited adverse impacts on the environment. But consumers might not be aware that:
- agrofuels do lead to GHG emissions;
- agrofuel feedstock cultivation might lead to adverse direct impacts on all areas of concern mentioned in the tables of section 1 (GHG emissions, biodiversity, soil, water, air) and also to adverse indirect impacts that are very poorly understood;
- with today's certification schemes, certified agrofuels come from feedstocks that are cultivated according to intensive farming practices with very little change towards less environmentally-harmful practices.

One may wonder whether agrofuels made from feedstocks cultivated according to conventional industrial farming practices are acceptable considering their large environmental impacts. However, it seems that very few certification schemes have gone as far as questioning conventional agriculture practises. Actually, considering the above tables, agrofuels produced from crops grown with conventional (industrial intensive) farming practices seem to be perfectly certifiable for most agrofuel certification schemes. Thus, agrofuel certification may appear as a legitimisation of industrial farming even though many consider it to be damaging for the environment (IAASTD, 2008).

Thus, numerous agrochemicals - that lead to water, air and soil pollution and contamination as well as to adverse impacts on biodiversity - are still permitted in most certification schemes that were compared earlier. Genetically Modified Organisms are permitted as agrofuel feedstocks for most schemes even though there is very little hindsight regarding their overall impacts on ecosystems. Mono-cropping is also perfectly permitted by most schemes, which seem to consider this is not a problem in terms of biodiversity even though mono-cropping is known for leading to higher needs in pesticide use and higher nitrogen leaching (Whitmore & Schroder, 2007). Finally, most schemes seem to put aside the fact that tillage necessarily leads to soil erosion, which is a major concern for GHG emissions as well as a misunderstanding of soil biodiversity functioning (Bourguignon & Bourguignon, 2009).

Thus, one can wonder whether (theoretically expected) GHG emission reductions of agrofuels can justify other environmental problems and enable loose certification of agrofuels.

4.1.5 Comparison of GHG default values

As can be seen in table 9 above, GHG emission targets are very different from one scheme to another.

One reason for these differences probably lies in the fact that GHG emission default values for specific agrofuels can also be very different from one LCA to another and thus from one scheme to another.

Apart from the RED and the RTFO, most schemes presented above did not have final GHG emission calculation methodologies or at least not enough tools for the calculation of GHG emission default values at the time of their publishing.

Although the French and British policies will be reviewed in detail in chapter 5, it was thought particularly interesting to compare GHG emission default values retained by the Renewable Fuels Agency in 2009, a French study of 2002, the European Commission's 2008 proposal for a Directive and the eventual 2009 Renewable Energy Directive.

The following graphs were made with GHG emission reduction default values from the following papers:

- "Bilans énergétiques et gaz à effet de serre des filières de production de biocarburants en France - Note de synthèse (Décembre 2002) " (Ecobilan/PriceWaterhouseCoopers, 2002a), called 'ADEME 2002' in the following graphs ;

- “Carbon and Sustainability Reporting Within the Renewable Transport Fuel Obligation - Technical Guidance Part 1 - Version 2.0 March 2009” (RFA, 2009a), called ‘RFA 2009’ in the following graphs;
- “Proposal for a Directive on the promotion of the use of energy from renewable sources - COM(2008) 19 final” (European Commission, 2008), called ‘EC 2008’ in the following graphs;
- “Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC” (European Commission, 2009a), called ‘EC 2009’ in the following graphs.

Figure 43: Wheat Ethanol GHG emission reduction default values

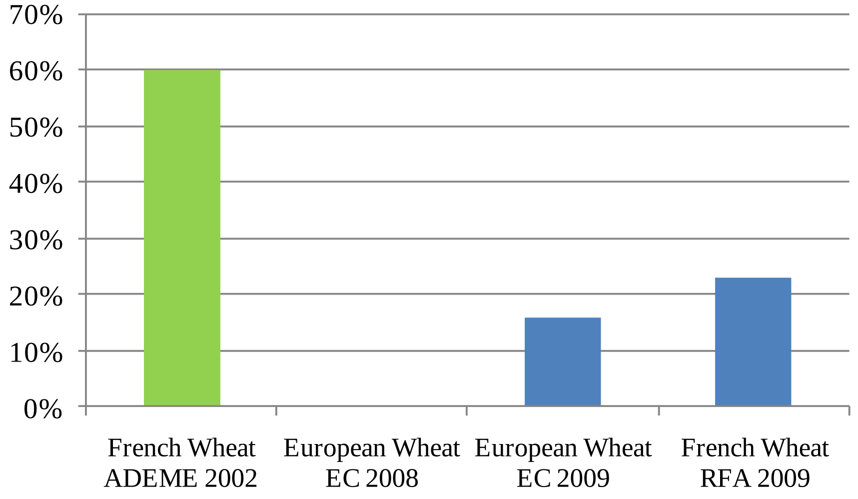


Figure 44: Sugar Beet Ethanol GHG emission reduction default values

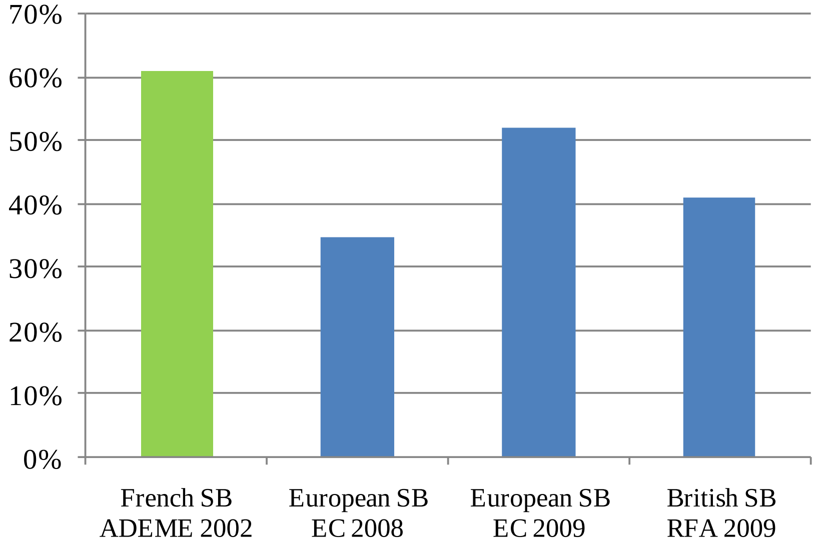


Figure 45: OSR agrodiesel GHG emission reduction default values

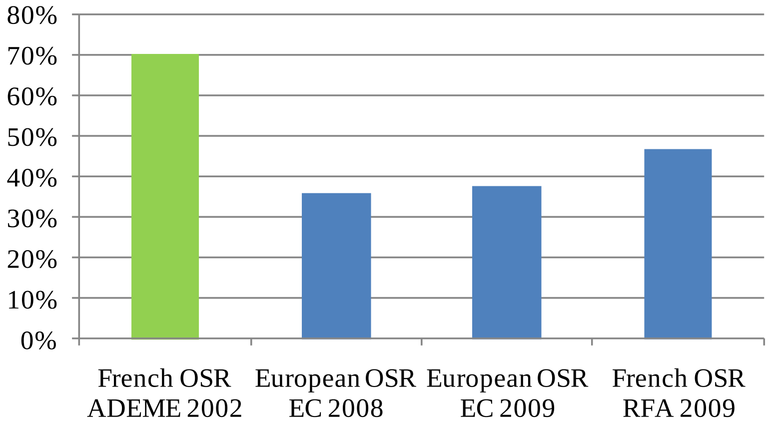
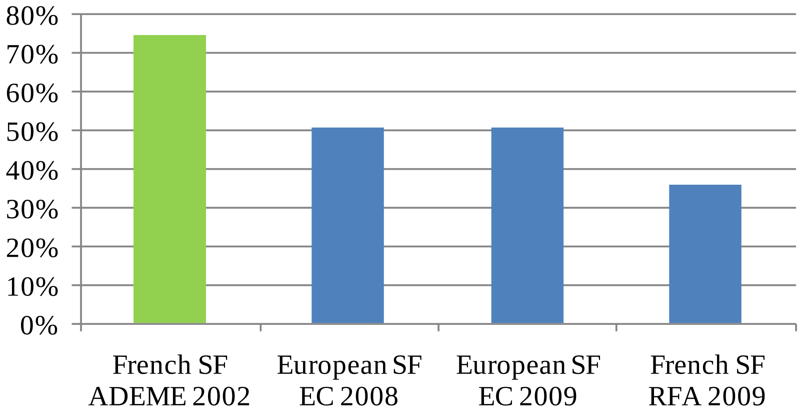


Figure 46: Sunflower agrodiesel GHG emission reduction default values



The first observation that comes from these graphs is that GHG emission reduction default values, though always positive (only European wheat ethanol has a default GHG emission reduction of 0% according to the 2008 European Commission proposal for a Directive), varies significantly from one paper to another.

The second observation is that the French 2002 report has the highest GHG emission reduction default values for all four selected agrofuels. As will be seen in the next chapter, the choice of such high default values is probably due to political and economic reasons and has little to do with objective science.

Then, one can observe that the default values are different between the European Commission 2008 proposal and the final 2009 Directive. Actually, GHG emission reduction default values were increased for all the above-presented agrofuels. One should also note that the GHG emission reduction target of the proposal and the Directive are 35% compared with fossil fuels. Interestingly, the GHG emission reduction default values for sugar beet and oilseed rape – both major EU-produced agrofuel crops – are respectively 35 and 36% in the 2008 proposal, that is to say just above the 35% threshold. One can notice that these default values were respectively increased to 52 and 38% in the final Directive, which show these agrofuels in a much more favourable fashion. This change leaves less ambiguity about the interest of the European Commission in these agrofuels, but raises questions as to the reasons for such increases in European agrofuel feedstock GHG emission default values.

Thus the choice of GHG emission reduction values for agrofuels may seem more like a political choice rather than a scientific one. However, it should be noted that the precautionary principle applies to GHG emission reductions further to the Climate Change Convention, which is legally binding upon most of the international community of states (United Nations, 1998). As such, any methodological uncertainty needs to be resolved in favour of addressing uncertainty on estimates of lower GHG emissions by placing a burden of proof on such advocates to demonstrate certainty. Otherwise, the higher default values of GHG emissions (or the lowest default values of GHG emission reduction) must be applied.

Next section will focus on GHG emission reduction calculation methodologies, which may also include a substantial part of subjectivity.

4.2 The importance of methodological bias on GHG emission reduction calculation

As seen earlier, GHG emission default values for specific agrofuels can be very different from one scheme to another.

GHG emissions are usually calculated in GHG LCAs, following specific guidelines explaining how LCAs should be performed (ISO standards 14040 to 14044). The results of GHG LCA can give ranges of GHG emissions, which can then be utilised by policy makers to decide on what value to keep as a minimum threshold for agrofuel GHG emission reductions.

However, ISO standards for LCAs allow much freedom regarding numerous points that greatly influence the calculation of GHG emissions and the final results.

Dorin & Gitz identified a number of controversies linked to agrofuels, among which some relate to the way their GHG emissions are calculated in GHG LCAs (Dorin & Gitz, 2008):
- the treatment of co-products has a large influence on GHG LCA results;
- fossil energy for machinery, agriculture and industrial buildings is generally not included in agrofuel GHG LCAs, which raises the question of the choice of boundaries;
- the choice of the emission factor of nitrous oxide (N_2O) dramatically influences GHG results;

- whether LUC GHG emissions are included and how they are calculated.

Actually, LCAs bring different results because methodological choices AND assumptions can vary widely from one LCA to another (Shapouri *et al.*, 2002; Elsayed *et al.*, 2003; Larson, 2006; Benoist *et al.*, 2008; Cherubini *et al.*, 2009).

This section aims at presenting and discussing methodological choices and assumptions that are part of GHG LCA methodologies and that largely influence GHG LCA results.

4.2.1 Lack of transparency of numerous agrofuel LCAs

For comparison between LCAs to be possible, it seems necessary that LCAs studies are completely transparent. However, Elsayed *et al.* showed in a 2003 report that most agrofuel LCAs lacked transparency (Elsayed *et al.*, 2003), at least at the time of the study (2003). For instance, among the 12 selected studies on rapeseed oil production, **only one was acknowledged as transparent**, while four were considered partly transparent and seven not transparent.

Figure 47: Relative transparency of studies reviewed by Elsayed *et al*.

Study	Results				Transparency	Country
	Energy	CO_2	Other GHG	Total GHG		
Culshaw & Butler, 1992	✓	✓	X	X	Partial	UK
IEA, 1994	X	X	X	✓	X	UK & USA
Gustavsson et al, 1995	X	✓	X	X	X	Sweden
Gover et al, 1996	✓	✓	✓	✓	Partial	UK
Spirinckx & Ceuterick, 1996	✓	X	X	✓	Partial	Belgium
Kaltschmitt & Reinhardt, 1997	✓	✓	✓	✓	✓	Germany
ECOTEC, 1999	X	✓	✓	✓	X	UK
ECOTEC, 2000	✓	✓	✓	✓	X	UK
Richards, 2000	✓	✓	✓	X	X	UK
ECOTEC, 2001	X	X	X	✓	X	UK
Beer et al, 2002	✓	✓	X	✓	X	Australia
Grover, 2002	✓	✓	✓	✓	Partial	UK

Source: (Elsayed *et al.*, 2003)

Thus, despite agrofuel GHG emissions being a very controversial issue (though less at the time Elsayed made his review), most of the LCAs analysed by Elsayed calculated GHG emissions (or energy ratios and/or simply CO_2 emissions) without sufficiently explaining how they did. This automatically casts a doubt on the objectivity of such studies and challenges their scientific rigour.

However, since agrofuels are much more of an issue today compared to the little production, consumption and media coverage they had before the mid 2000s, most LCAs (but not all) seem to be much more transparent nowadays.

However, agrofuel GHG emission calculation is a complex task and requires not only numerous data but also diverse methodological choices and assumptions all along the calculation path. Therefore, even if agrofuel LCAs are more transparent today compared to what they used to be, it remains difficult to really address all the nuances of agrofuels' GHG emissions because agrofuel LCAs are very difficult to compare.

4.2.2 Treatment of co-products

The first and most criticised methodological choice probably lies in how co-products are treated. As was seen in chapter 3, agrofuel production also leads to the production of an important amount of co-products. Different strategies exist to take into account (or not) co-products and assign to them a share of the agrofuel production chain GHG emissions (cf. chapter 3):
- no allocation (in which case, all the GHG burden is put on agrofuels);
- economic (monetary value), mass, energy (and even volume) allocation;
- system expansion, also called substitution approach.

Shapouri *et al.* showed in several studies that co-product treatment had a very large influence on the energy ratio of maize ethanol (Shapouri *et al.*, 1995; Shapouri *et al.*, 2002). His 2002 study aimed at determining what share of energy cost was to be attributed to agroethanol and what share should be attributed to its co-products in order to find out whether and to what extent agroethanol would provide more energy than was needed for its production. The figures regarding the allocation of the energy input to ethanol and its co-products – these figures are exactly the same for any burden, whether it is energy input, GHG emissions or any other burden – are presented in the figure below, in which 'replacement' should be understood as 'substitution':

Figure 48: Ratio of burden between maize agroethanol and its co-products

	Ethanol	Coproduct
	Percent	
Output weight basis:		
Wet mill	48	52
Dry mill	49	51
Weighted average	48	52
Energy content:		
Wet mill	57	43
Dry mill	61	39
Weighted average	58	42
Market value:		
Wet mill	70	30
Dry mill	76	24
Weighted average	72	28
Replacement value:		
Wet mill	81	19
Dry mill	82	18
Weighted average	81	19

Source: Adapted from Shapouri *et al.* (2002)

Thus, depending on what type of co-product treatment is chosen, **from 48 to 82%** of the GHG emissions associated with the agrofuel production chain are attributed to agroethanol, with the substitution approach appearing as the most conservative and the mass allocation approach the most favourable.

Such finding is confirmed by Benoist *et al.* who consider the choice of allocation rule as one of the most important parameters influencing GHG LCA results (Benoist *et al.*, 2008; Benoist, 2009). Indeed, GHG credits from co-products are often a significant source of GHG emission reduction in agrofuel chains. If co-products were not taken into account, lots of agrofuels, and particularly maize ethanol, would probably have higher direct GHG emissions than fossil fuels (Patzek *et al.*, 2005; Pimentel & Patzek, 2005; Patzek, 2006).

Although the ISO 14040-14049 standards do not specify what allocation to follow, the ISO 14044 standard suggests that treatment by allocation should be avoided and that system expansion should be preferred. Indeed, allocation procedures are often thought to be arbitrary because they do not reflect the reality of the fate of the co-products (apart maybe from energy allocation when co-products are actually burnt for energy generation).

As a matter of fact it sounds illogical to use for instance an energy allocation when co-products are not used for their energy content. DDGS from maize ethanol or rapeseed meal from oilseed rape agrodiesel production are actually commonly used as fodder for livestock.

Nevertheless, the European Commission decided in its 2009/28/EC Directive that the artificially favourable rule of energy allocation will be preferred in agrofuel GHG LCAs.

Monetary allocation can be thought to be interesting in that it can reflect the reason why products are produced (for instance soybeans are produced for soymeal as animal feed rather than for soymethyl ester which can be considered as a by-product of soymeal production). However, prices can fluctuate very rapidly and usually reflect a much distorted reality because of subsidies and above all because most externalities (environmental and social) are so far rarely taken into account in prices.

According to a study by Reinhardt & Fehrenbach, the allocation procedures that are the most beneficial to rapeseed methyl ester (RME) in terms of GHG emission reduction are mass allocation (chosen by the French study of 2002 (Ecobilan/PriceWaterhouseCoopers, 2002b)), then price allocation and finally energy allocation (Reinhardt & Fehrenbach, 2007).

The substitution approach (or system expansion) is nearly all the time preferred because it is considered to give a more realistic estimate of the actual GHG emissions avoided thanks to the production of co-products that substitute for other products that would otherwise have needed to be produced (Shapouri *et al.*, 1995; Elsayed *et al.*, 2003; Edwards *et al.*, 2007b; Benoist *et al.*, 2008; Bauen *et al.*, 2009).

There are very few examples of papers not choosing the substitution approach, apart from the European Renewable Energy Directive (Bauen *et al.*, 2009) and the French paper of ADEME 2002 cited above.

However, in spite of its attractiveness, the substitution approach is not so simple partly because there can be changes in demand, or co-products do not necessarily entirely substitute for what would have been consumed instead (Bio Intelligence Service, 2008a). Therefore, the substitution approach can lead to very complex modelling wherein elasticity of substitution between products needs to be taken into account (Banse *et al.*, 2008).

Moreover, it is rather impossible to know what agrofuel co-products really substitute for since what they substitute for precisely has not been consumed.

Thus the substitution approach can lead to comparisons that are not necessarily representative of reality. For instance, glycerin, which is an important co-product linked to the production of rapeseed methyl ester (RME) – that is agrodiesel from oilseed rape – can be said to substitute for glycerin chemically synthesised from fossil fuels. Since the route for chemically-synthesised glycerin production is extremely energy and GHG intensive, such choice of substitution approach enables RME to get important GHG credits (Edwards *et al.*, 2007a). However, due to the recent expansion of agrodiesel production (especially in Europe), the glycerin market is close to saturation (Benoist *et al.*, 2008) and it becomes increasingly uncertain that glycerin as a co-product from agrodiesel production really substitutes for chemically-synthesised glycerin. Within a substitution approach, if glycerin from agrodiesel production no longer substitutes for its chemically-synthesised equivalent and is better used as an energy source or an animal feed, the overall GHG emission reduction of rapeseed methyl ester will decrease (Benoist, 2009) and should be counted as such.

It also is very difficult to assess what co-products that can be used as animal feed really substitute for. Indeed, DDGS, rapemeal and sunflower meal do not have the same energy and protein content than soymeal (which is the main source of protein for livestock in the EU). Furthermore, they are not as easily digested as soymeal (Croezen & Brouwer, 2008). Therefore, such products can only replace a part of the soymeal that is currently imported as animal feed (a part that varies according to the type of animal and its capacity of agrofuel co-product digestion compared with soymeal). Finally, in a country like France, wheat DDGS seem to lose the "competition" with rapemeal and sunflower meal because they are less protein-rich and above all because they are more expensive to produce because of the dehydration step that is needed for their production (Sadones, 2006b). Therefore, there is a big question mark about what French DDGS will actually substitute for and even about what they can be used for. Again, the burden should be placed on the agrofuel producer to demonstrate valid substitution for any greenhouse gas saving to be distributed from this substitution approach.

It seems that apart from giving favourable GHG emission reductions to some agrofuels, the only interest of the energy allocation procedure chosen by the European Commission lies in the fact that it only involves easy static calculations (the ratio of energy content between agrofuels and co-products does not change) that do not require complex modelling. However, one can have doubts about the robustness of such approach in terms of proximity with the reality that one should aim for when assessing agrofuel production overall impacts on the environment.

The mass allocation chosen in the 2002 French report by Ecobilan (Ecobilan/PriceWaterhouseCoopers, 2002d) has similar problems of representativeness than the energy allocation chosen by the EC and was harshly criticised for introducing a bias in favour of agrofuels (Sourie *et al.*, 2005; Sadones, 2006a; Benoist, 2009). Other problems linked to co-product allocation in this French report will be presented in chapter 5.

As a conclusion, allocation procedures have little physical logic, temporal logic (due in part to changing market conditions) or rationality and only have the advantage of being simple to use for quick results, whereas the substitution approach that seems closer to reality is very complex to put in place, and can also lead to mistakes.

4.2.3 Annualisation of LUC/iLUC GHG emissions

GHG emissions due to direct and indirect LUC are very large (cf. chapter 3). In order to give a realistic account of agrofuel overall GHG emissions, such large emissions need to be taken into account. Methodologies exist and are widely used for the calculation of LUC GHG emissions (IPCC, 2003).

iLUC GHG emissions can also be calculated in theory. Once land (or mix of lands) that is associated with iLUC has been determined, iLUC GHG emissions can be modelled. Their annualisation follows the same logic than that which will be explained further in this chapter.

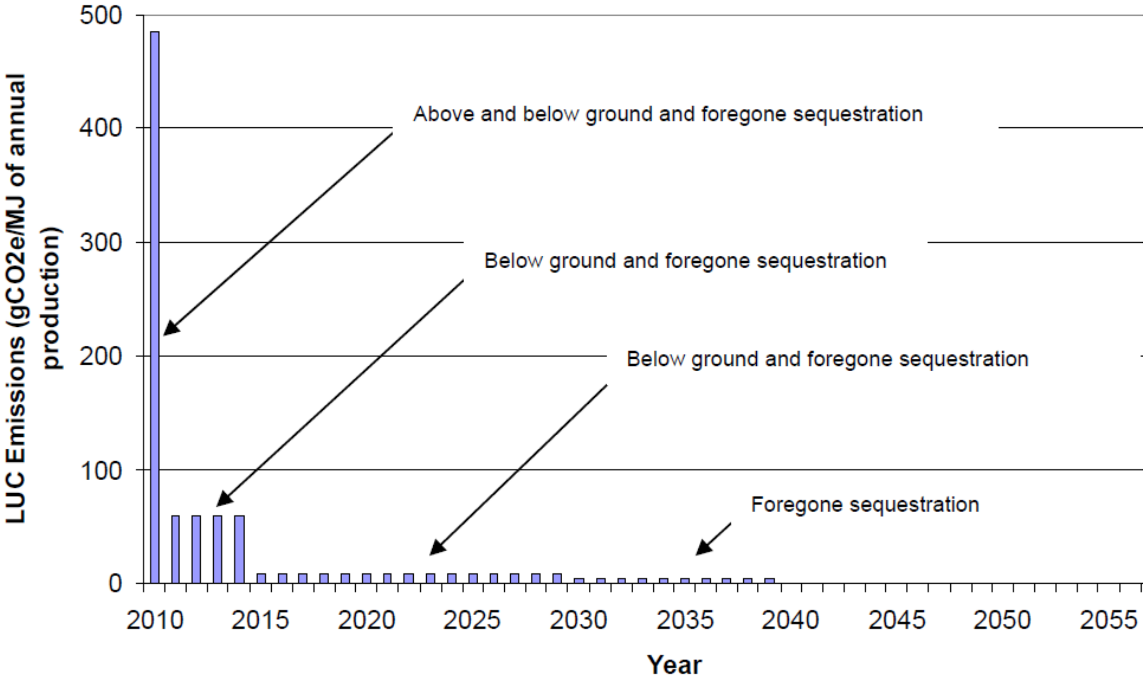
Different types of GHG emissions are encountered when land conversion occurs:
- large amounts of above-ground biomass burn and/or are removed in the first place, as soon as land conversion occurs (especially for forestland);
- below-ground biomass burns or degrades as soon as land is converted. Below-ground biomass decay emits large amounts of GHG for about 5 years after land conversion has taken place. Then, original below-ground biomass still decays for about 15 years, also leading to GHG emissions;
- foregone sequestration GHG emissions are emitted for a length of time that depends on the state of maturity of the ecosystem when it was cleared to leave place to agrofuel feedstock cultivation. Foregone sequestration GHG emissions correspond to the emissions which would have been avoided if the original grassland or forest that was cleared could have continued to grow and sequester carbon from the atmosphere.

Thus, the GHG emission profile of a land conversion can be divided into 4 phases, the durations of which greatly vary:
- Phase 1 corresponds to year 1, when above-ground biomass is destroyed or removed, as well as a lot of below-ground biomass, which creates very large ‘one-off’ GHG emissions. Foregone sequestration for year 1 also needs to be taken into account.

- Phase 2: after the initial destruction of above-ground biomass, below-ground biomass still emits large amounts of GHG emissions to which foregone sequestration adds up.
- Phase 3: below-ground biomass produces GHG emissions in smaller quantity than during phase 2 and foregone sequestration continues to be taken into account.
- Phase 4: original below-ground biomass does not produce net GHG emissions any longer but the remaining of foregone sequestration has to be taken into account.

An example of the evolution of land conversion emissions can be seen in the following figure:

Figure 49: Example of land conversion GHG emission profile



Source: (Air Resources Board, 2009)

Thus, agrofuels produced from feedstocks cultivated on land following LUC are a source of LUC GHG emissions that are particularly important right after land conversion and that greatly vary over time. For agrofuels produced after change in land use from one specific land mass not to have GHG emissions that vary over time, it is common to annualise LUC GHG emissions.

Annualisation can be made over different time scales and discount factors can be used or not, which leads to very different results.

The use of discount factors enables us to give more importance to present time rather than to the future, but leads to artificially favourable GHG emission reductions.

Typical time allocations for annualisation usually range between 20 and 100 years (Cornelissen & Dehue, 2009). These durations are arbitrary but have a large influence on the results of (i)LUC GHG emissions calculations. While the RED and the RFA promote an annualisation over 20 years, both the EPA and the LCFS favour annualisation over 100 years (Bauen *et al.*, 2009), which considerably decreases the influence of LUC GHG emissions on agrofuels' overall GHG emissions as shown by Benoist (2009).

The following table from the EPA compares several agrofuels' overall GHG emissions depending on methodological choices for the accounting of iLUC GHG emissions:

Table 18: Lifecycle GHG emission reduction results for different time horizons and discount rates

Fuel Pathway	100 year, 2% Discount Rate	30 year, 0% Discount Rate
Corn Ethanol (Natural Gas Dry Mill)	-16%	+5%
Corn Ethanol (Best Case Natural Gas Dry Mill)[2]	-39%	-18%
Corn Ethanol (Coal Dry Mill)	+13%	+34%
Corn Ethanol (Biomass Dry Mill)	-39%	-18%
Corn Ethanol (Biomass Dry Mill with Combined Heat and Power)	-47%	-26%
Soy-Based Biodiesel	-22%	+4%
Waste Grease Biodiesel	-80%	-80%
Sugarcane Ethanol	-44%	-26%
Switchgrass Ethanol	-128%	-124%
Corn Stover Ethanol	-115%	-116%

Source: (Office of Transportation and Air Quality, 2009)

Compared to a 30-year annualisation with no discount rate, the 100-year annualisation with a 2% discount rate favours all fuels, especially those with the highest risks of iLUC GHG emissions of the list such as maize ethanol, soy agrodiesel and sugarcane ethanol.

In order to be closer to the reality of the impacts of agrofuels, it seems that the annualisation of LUC and iLUC GHG emissions should be done according to the time scale that corresponds to the length of the agrofuel feedstock production project.

However, one cannot know before hand how long such projects will take place. Even though 20 years is often chosen as a reference for annualisation, it seems that such a time length is not reasonable insofar as it "does not correspond to a foreseeable future" (Bauen *et al.*, 2009). This is why Bauen *et al.* suggest that 15 years should be used as a reference for LUC GHG emissions annualisation. This choice would increase the annual GHG emission burden from LUC in agrofuels' overall GHG emissions.

It should also be noted that most LUC GHG emissions occur within 4-5 years after LUC (cf. figure 49). Since action needed to mitigate climate change is urgent (IPCC, 2007a), it is probably counter-productive to promote fuels that would only start to be environmentally-friendly once all their associated carbon debt (cf. this notion in chapter 3 section 3.1.3.3) is eventually 'reimbursed'.

This issue of annualisation can be circumvented for direct LUC GHG emissions when one chooses to ban agrofuels that cause direct LUC GHG emissions such as those due to the conversion of a forest or grassland to a cropland for agrofuel feedstock production. The carbon- and biodiversity-criteria of the Renewable Energy Directive for instance are meant to make sure that agrofuels whose feedstock cultivation caused LUC are not taken into account and do not contribute to national and European targets. However, in most cases such criteria are not sufficient to address iLUC, which will still be indirectly caused by agrofuel feedstock production that necessitates agricultural land.

4.2.4 Global Warming Potentials

As seen in the introduction, GHGs do not have the same impact on climate. GWP (Global Warming Potential) is an indicator of the relative contribution of one unit of mass of GHG compared with one unit of mass of CO_2 that is chosen as a reference for this indicator. GWPs are commonly used to convert emissions of GHGs into gCO_2e (grams of CO_2 equivalent) in order to be able to add up all GHG emissions together and get a single figure.

However, climate science is still in its infancy and atmospheric concentrations of GHG evolve, thus GHG GWPs have constantly been revised (cf. following figure with SAR = second assessment report of 1995, TAR = third assessment report of 2001 and AR4 = fourth assessment report of 2007):

Table 19: GWP of the main greenhouse gases depending on time horizon

Gas	Lifetime (years) AR4	Unit	Global Warming Potential								
			20 years			100 years			500 years		
			SAR	TAR	AR4	SAR	TAR	AR4	SAR	TAR	AR4
CO_2	Variable	kg eq CO_2 / kg CO_2	1	1	1	1	1	1	1	1	1
CH_4	12	kg eq CO_2 / kg CH_4	56	62	72	21	23	25	6.5	7	7.6
N_2O	114	kg eq CO_2 / kg N_2O	280	275	289	310	296	298	170	156	153
CCl_3F	45	kg eq CO_2 / kg CCl_3F		6,300	6,730	3,800	4,600	4,750		1,600	1,620
CCl_2F_2	100	kg eq CO_2 / kg CCl_2F_2		10,200	11,000	8,100	10,600	10,900		5,200	5,200

Source: Personal diagram made with data from Forster *et al.* (2007) and Ramaswamy *et al.* (2001)

Indeed, there still are numerous uncertainties regarding figures of GWPs. For instance methane GWP seems to be underestimated (Boucher *et al.*, 2009c) while the GWP of N_2O was reduced between SAR and TAR before being increased again in AR4.

Besides, the use of GHG GWPs raises numerous questions, especially in GHG LCAs. Indeed, according to Forster *et al.*, the Global Warming Potential is a tool that “has been widely debated since its introduction” because emissions that are equal in GWP-weighted emissions can be different in terms of the temporal evolution of climate response (Forster *et al.*, 2007).

In order to follow changes in GHG GWPs, one can use dynamic GWPs to give a more realistic account of agrofuels’ GHG implications (Benoist, 2009). Then it appears that agrofuels for which LUC or iLUC GHG emissions are taken into account, GHG emission results are generally lower with annualisation methods than when dynamic GWPs are used (Kendall *et al.*, 2009; Levasseur *et al.*, 2010).

Another problem lies in the fact that the time horizon of 100 years chosen by the Kyoto Protocol has no scientific basis (IPCC, 1994; Fearnside, 2002). However, the choice of one time horizon rather than another can lead to agrofuels meeting GHG reduction requirements or not (Levasseur *et al.*, 2010).

For instance, methane has a lifetime of 12 years and a GWP that is much higher than that of CO_2, especially for a 20-year time horizon because it is a short-lived GHG. Since climate change is generally considered as requiring urgent action, many advocate for methane time horizon to be 20 years rather than 100 years (Eco-cycle, 2008; Goodland & Anhang, 2009). Thus, the choice of time horizon for agrofuels’ GHG emission calculation needs to be explained otherwise it may appear as another methodological bias used to improve agrofuels’ perceived GHG implications.

In this regard, it should be noted that the annualisation of LUC GHG emissions over 20 years is inconsistent with the widespread use of a 100-year time horizon.

Thus, although fixed GWPs may simplify agrofuels' GHG emission calculations, they pose problems because their value is not only uncertain but also dynamic. Moreover, differences in GHG GWPs depending on time horizons introduce a new methodological bias that needs to be justified.

4.2.5 Choice of baselines

Several baselines are necessary in order to calculate agrofuels' GHG emission reductions, such as:

- GHG emissions of the 'substituted' unit of fossil fuel;
- GHG intensity of the product that is substituted for by newly produced agrofuel co-products (when the system expansion approach is used);
- choice of a scenario concerning land-use in case of LUC.

a) If one chooses high GHG intensity reference values for fossil fuels, then it is easier for agrofuels to achieve high GHG emission reductions since they are compared with abnormally high reference values. However, since fossil fuels GHG intensities are expected to increase (because of the increase in energy input needed to extract unconventional oils) agrofuels may mathematically show better GHG emission reductions in the years to come anyway.

The following table presents the different reference values chosen by selected schemes or reports for fossil fuels' GHG intensity:

Table 20: Default GHG intensity of fossil fuels

	ADEME 2002	BioIS 2008	BioIS 2009	BioIS 2010	DfT 2008	RFA 2009	RED 2009	LCFS 2010
Petrol	85.9	85.12	**101.8**	90.1	84.8	85	83.8	95.86
Diesel	79.3	87.09	**96.0**	91.4	86.4	86	83.8	94.71

Source: (Ecobilan/PriceWaterhouseCoopers, 2002a; Bio Intelligence Service, 2008a; DfT, 2008; Bio Intelligence Service, 2009; RFA, 2009b; Bio Intelligence Service, 2010; State of California, 2010)

Apart from some surprisingly high GHG emission intensities (**especially those found in the 2009 BioIS report**, which will be further investigated in chapter 5), the values chosen by

European schemes or studies are usually comparable and lower than those chosen by the state of California for its LCFS.

It should be noted that when agro-ETBE is compared with fossil MTBE for GHG emission reduction calculations, it looks very good GHG-wise because fossil MTBE has a higher GHG intensity than petrol (Bauen *et al.*, 2008). However, such comparison may seem questionable insofar as both agro-ethanol and agro-ETBE act as fuel oxygenates but agroethanol is never compared with MTBE. Moreover, agro-ETBE is produced in much larger quantities than MTBE was.

Thus, it may look more objective to talk about agrofuels in terms of their absolute GHG emissions rather than in terms of GHG emissions compared with fossil fuels.

b) Then if the co-product treatment methodology chosen is substitution, it is important to carefully determine what agrofuel co-products really displace (as closely as possible to reality). In order to improve agrofuel direct GHG balance, it can be tempting to present agrofuel co-products as substitutes for GHG-intensive products, which would once again mathematically improve agrofuel GHG balance.

c) Finally, every time land is used for agrofuel crop cultivation it is necessary to assess what this land displaces and what would have happened at the global scale if this land had not been used for agrofuel production. This is particularly important when the land used for agrofuel feedstock production previously was a high-carbon stock: would that land have continued to sequester carbon or was it meant to be converted into an agricultural land anyway?

Moreover, as seen in section 1, there usually is a reference date regarding the nature of the land that is used for agrofuel crop cultivation. If the land was a protected area or a high-carbon stock at this very date, then it cannot be used for certified agrofuel feedstock cultivation. One can notice that the reference dates in the selected agrofuel certification schemes are rather recent (all after November 2005) despite numerous international summits stressing the importance of forests for biodiversity and carbon sequestration well before 2005. Therefore, such choices of reference dates somehow legitimise all LUC that occurred before 2005. For instance, it is not allowed to produce palm oil agrodiesel from November 30th 2005 under the RTFO, but there is no problem if the forest was cleared for palm oil plantation in July 2005 for instance. However, deforested areas may bring more environment benefit if they were reforested than if they are used for agrofuel production (Righelato & Spracklen, 2007).

4.2.6 Choice of boundaries

The choice of boundaries is crucial for realistic GHG accounting of agrofuel systems to be made. Thus, for GHG LCAs to be representative of reality, it seems important to include in the system the construction and the exploitation of facilities that are used for agrofuel production. For instance, palm oil agrodiesel production requires the construction of numerous mills because fresh fruit bunches need to be processed within 24 hours of harvest (Wakker, 2005). If palm oil mill construction is not included in palm oil agrodiesel LCAs, then the GHG LCA results will be an underestimation of the actual direct GHG emissions due to palm oil agrodiesel production.

Moreover, there are two different ways to see agrofuel impacts and thus two very different types of LCAs (Brander *et al.*, 2008):

- Attributional LCAs (ALCAs) provide information about the impacts of the processes to produce a product but do not consider indirect impacts due to changes in the output of the product (narrow boundaries);
- Consequential LCAs (CLCAs) on the opposite provide information about the consequences of changes of output of a product (extended boundaries).

Thus, ALCAs are particularly useful if one wants to find out how to reduce direct impacts due to the production of a product while CLCAs enable us to give results on how impacts evolve when the output of the product changes. In a way, CLCAs enable to extend boundaries of the subject they analyse. Although CLCAs are much more complex to do than ALCAs and are dependent on economic models, they are particularly useful to inform policy makers on the broader impacts of policies intended to change levels of production (Brander *et al.*, 2008).

According to Brander *et al.*, most agrofuel policies “tend not to distinguish between […] consequential LCA (CLCA) and attributional LCA (ALCA). Failure to distinguish between CLCA and ALCA can result in the wrong method being applied, a combination of the two approaches within a single analysis, a misinterpretation of the results, or an unfair comparison of results derived from different methods” (Brander *et al.*, 2008). However, despite this caution, Bauen *et al.* recommend a mixed approach of CLCA and ALCA for practicality reasons (Bauen *et al.*, 2009).

Expanding agrofuel consumption leads to considerable changes in the global acreage of specific crops, which automatically displace other crops (gains in yields are not sufficient to compensate for the increase in production). In Europe, although rapeseed oil for food consumption has remained steady during the last years, the production of rapeseed oil for agrodiesel production has very quickly increased (cf. figure below):

Table 21: Utilisation of rapeseed oil in the EU-25 (in million tonnes)

Marketing year	Total utilization	Agrodiesel	Food
2002/03	4.14	1.45	2.69
2003/04	4.38	1.77	2.61
2004/05	5.37	2.70	2.67
2005/06	6.60	3.98	2.62
2006/07 (estimates)	7.24	4.65	2.59

Source: (Jacquet *et al.*, 2007)

Thus, in 2006/2007, 64% of the OSR consumed in the EU was for biodiesel production compared to 35% in 2002/2003. The production of additional OSR for agrodiesel production needs land, and thus displaces other crops (yields cannot have sufficiently increased to compensate for such a level of rapeseed production for this new outlet that is agrodiesel). This displacement of crops may eventually lead to changes in land-use either in Europe (for instance some grassland could be ploughed up and converted to arable land) or outside Europe (for instance, displaced crops could be cultivated on formerly forested areas in South countries). Indirect land-use change linked with this displacement and its related GHG emissions are potentially high but also extremely difficult to determine precisely because it is not possible to assess where displaced crops (or the crops that substitute for displaced crops) are cultivated.

Very complex models are often used to try to determine iLUC but Fritsche also developed a more pragmatic approach called ‘iLUC risk-adder’. Considering agrofuel producing regions and the GHG emissions of ecosystems that might undergo LUC in these regions, Fritsche *et al.* determined a theoretical iLUC factor of 400 tCO_2/ha, that is 20 tCO_2/ha*a when annualised over a 20-year period (Fritsche *et al.*, 2009). When applied to main agrofuels, the following figures for iLUC are found:

Table 22: GHG emissions including different iLUC factors, (in gCO_2/MJ)

	Total GHG emissions including part of iLUC factor (gCO_2/MJ)				
Agrofuel	Minimum	Medium	Maximum	Direct GHG	iLUC factor
Rape Methyl Ester, EU	117	188	260	46	284
Palm Methyl Ester, Indonesia	45	64	84	26	76
Sugar cane ethanol, Brazil	36	42	48	30	24
Maize ethanol, USA	72	101	129	43	116
Wheat ethanol, EU	77	110	144	44	132

Source: (Fritsche *et al.*, 2009) and personal calculations from Fritsche *et al.*(2009)

Minimum, medium and maximum iLUC factors respectively correspond to 25%, 50% and 75% of the total iLUC factor (calculated and shown in the last column of the above table). Such figures should be compared with GHG emissions of fossil fuels that are about 85 gCO_2e/MJ for diesel and petrol.

With this methodology, agrofuels with the highest iLUC GHG emissions are those that come from crops with the lowest agrofuel output per hectare. Interestingly, within the current LCFS methodology, maize ethanol receives a 30 gCO_2e/MJ iLUC premium (which is about 25% that calculated by Fritsche), while Brazilian sugarcane has a 46 gCO_2e/MJ iLUC premium (nearly twice that calculated by Fritsche) (State of California, 2010).

It should be noted that agrofuels' system boundaries could be extended further than just oil mill construction or iLUC. For instance, in an attempt to discredit iLUC GHG emissions from agrofuels, Liska & Perrin suggest that if iLUC impacts were to be taken into account for agrofuels then indirect effects such as wars due to oil should be included in oil GHG LCAs (Liska & Perrin, 2009). Actually, this point is rather interesting and in a way, oil wars should be included in oil GHG LCAs. However, agrofuels' development might also lead to conflicts relating to land appropriation that might result in wars, but this can only be seen *a posteriori*. In fact, the ideal boundaries are probably extendable to the entire world: this would enable a comparison of a world with the production of a certain amount of agrofuels and another world with the production of an equivalent amount of oil. The difference of the total GHG emissions from these two worlds would provide results as to how much GHG emissions or reductions agrofuels enabled. However, such comparison can only be based upon speculation as it is not possible to predict all of the consequences of the increase in agrofuels' production on the state of the world.

In conclusion, the choice of boundaries is an extremely complex topic. It seems important to include at least all energy processes and GHG emissions (including estimates of iLUC GHG emissions) linked with agrofuel production in order to obtain estimates of agrofuels' GHG impacts that are as close as possible to reality.

4.2.7 N_2O emissions from nitrogen fertilisers

N_2O (nitrous oxide) is a very potent GHG (100-year GWP = 296 kg eq CO_2 / kg N_2O) that significantly contributes to agrofuels' overall GHG emissions (Elsayed *et al.*, 2003; Bio Intelligence Service, 2008a). Its main sources are (Edwards *et al.*, 2007a):

- nitrogen fertiliser production;
- emissions from the field (cf. section 3.1.3.4 of chapter 3), that can be divided into direct N_2O emissions, secondary emissions (due to the volatisation of NH_3 and NO_x) and off-site emissions (due to the runoff and leaching of N fertilisers).

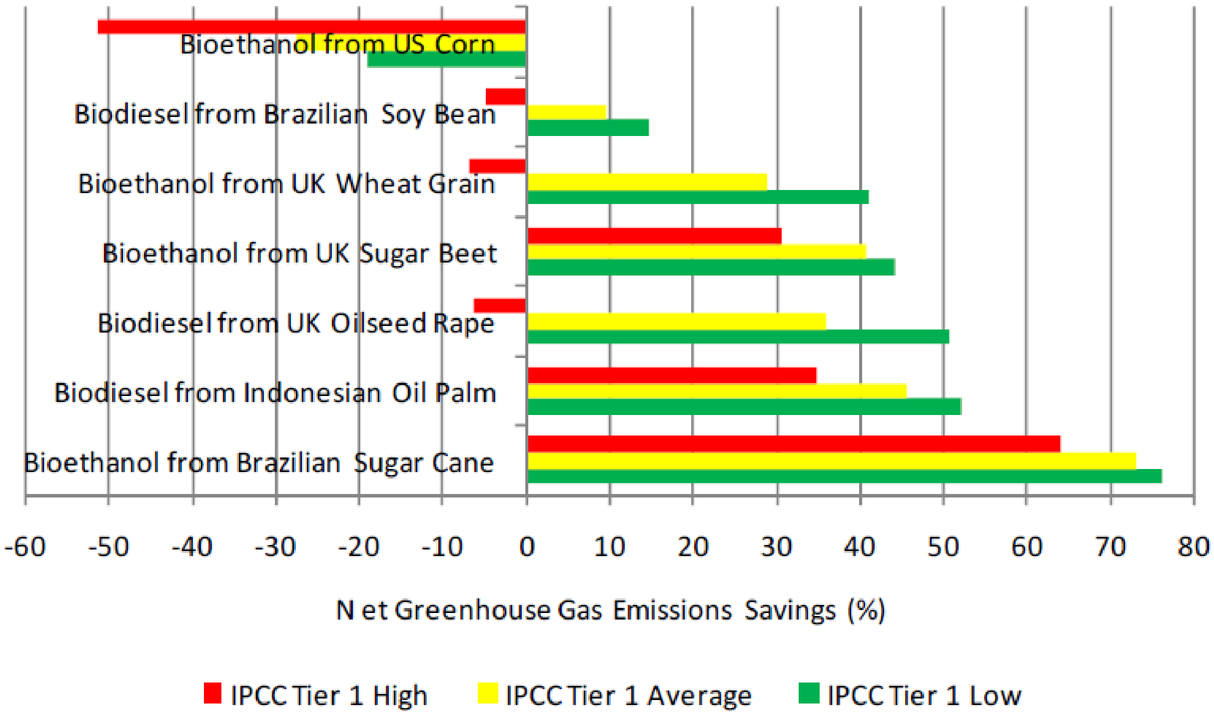
Whereas N_2O emissions due to fertiliser production can be easily determined, N_2O emissions from the field depend on numerous variables including soil nitrogen concentration (partly linked to nitrogen fertiliser application), soil moisture and soil temperature (Skiba *et al.*, 1996) but also crop type (Bio Intelligence Service, 2008a), soil type and tillage practices (Edwards *et al.*, 2007a). Indeed, the biological mechanisms leading to N_2O emissions are very complex and highly dependant upon local specificities (Favier *et al.*, 2008).

Whereas the IPCC proposes a simple methodology with a proportionality relationship between nitrogen fertiliser input and direct N_2O soil emissions (de Klein *et al.*, 2006) by the means of a single 1% emission factor, Edwards *et al.* suggest there is no such proportionate link and advocates the use of a soil chemistry model (DNDC – DeNitrification DeComposition model developed by the University of New Hampshire) applied to a database of well-referenced fields in terms of soil type, meteorology and fertiliser application rates (Edwards *et al.*, 2007a). Indeed, it is acknowledged that there is a variation of more than 100 times in N_2O emissions in EU fields (Edwards *et al.*, 2008), which gives little credit to the idea that N_2O emissions follow a simple proportionality rule with N rates of application.

Indeed, the IPCC's range of uncertainty for the direct emission factor of N_2O per amount of N fertiliser is very large (0.003 to 0.03 kg N_2O–N (kg N)$^{-1}$). Interestingly, the IPCC only recently decreased the direct N_2O emission factor, which used to be 1.25 % prior its new value of 1% (Salmon, 2008).

Mortimer *et al.* made calculations of GHG emissions from agrofuels with different N_2O emission factors within the range of uncertainty presented in the IPCC Tier 1 approach. The following figure shows that the influence of N_2O emission uncertainties can be very large depending on agrofuels that are considered:

Figure 50: Effect of uncertainty in soil N_2O emissions on GHG emissions savings



Source: (Mortimer *et al.*, 2009)

The fact that so many agrofuel certification schemes and agrofuel policies rely on this single emission factor from the IPCC methodology is unacceptable in view of the targets of GHG emission reductions that are expected from agrofuels. Indeed, with such a large uncertainty on the accounting of N_2O emissions, numerous agrofuels might not achieve overall (direct) GHG emissions reductions compared with their fossil fuel equivalents.

In addition, Crutzen *et al.* published in 2007 a critical study performing a top-down review of N_2O emissions at the global scale which concluded that N_2O emissions from cultivated soils had been largely underestimated (Crutzen *et al.*, 2008). The study found that a more appropriate emission factor for N_2O from arable land receiving N fertiliser should range between 3 and 5% compared with the IPCC figure of 1.325 % (direct + secondary + off-site emissions). This finding is crucial because when such an emission factor is used for GHG emission calculation for agrofuels, it is calculated that most agrofuels may not provide any GHG benefit compared with fossil fuels.

Although Crutzen's report underwent a lot of criticism (Mortimer *et al.*, 2008) it nevertheless had the merit of raising the question of N_2O emission factors which fuelled intense discussion on the subject.

It should be noted that according to Bernard Seguin from INRA, Lex Bouwman, one of the lead authors of the IPCC chapter on N_2O emissions, would now favour a 2.7% emission factor for N_2O (Salmon, 2008).

It also appears that several studies which did not follow the IPCC Tier 1 approach used various emission factors. For instance, the 2002 ADEME/DIREM report used emission factors determined in 1996 by Skiba (Skiba *et al.*, 1996) for several UK fields (Ecobilan/PriceWaterhouseCoopers, 2002b). As will be seen in chapter 5, these local emission factors that are well-below the IPCC default emission factor enabled French agrofuels to be seen in a more positive fashion.

A more extreme example is Sheehan's 1998 life cycle inventory of US soybean agrodiesel (Sheehan *et al.*, 1998). Sheehan *et al.* seem at first sight to take N_2O emissions very seriously as they acknowledge that "the amount [of nitrogen applied to soil as fertilizer and released into the atmosphere as N_2O and NO_x] depends on the quantity and type of fertilizer, soil conditions and water content, crop type, agricultural practices, and weather conditions, particularly rainfall". Sheehan *et al.* even provide typical ranges of values for N_2O emissions from maize and barley cultivation and talk about on-site and off-site emissions. However, they conclude their section on NO_x and N_2O emissions from soil with the following paragraph:

> *"However, the lack of consistent data and high degree of variability in soil emission measurements prevents us from deriving a meaningful expected soil emission estimate for soybeans. Therefore, although the range of values for possible N_2O and NO_x emissions is available, the uncertainty involved is too great to determine a meaningful estimate. For this model the field emissions for N_2O and NO_x will not be reported to prevent any misinterpretation of the overall results"*

In other words, N_2O emissions associated with soybean cultivation are ignored, supposedly because of uncertainties. However, one can notice that the executive summary of this study presents 'biodiesel' as an option to mitigate greenhouse gas emissions since soybean agrodiesel would enable precisely 78.45 % CO_2 emission reduction compared to fossil diesel. The high accuracy of this double-digit figure associated with the fact that N_2O emissions are ignored totally discredit the conclusions of this study.

Even though the debate on soil N_2O emissions is far from concluded, thanks to Crutzen's controversy, it becomes harder nowadays to ignore N_2O emissions as Sheehan did in 1998.

4.2.8 Problems with the units for agrofuels' supposed GHG emission reductions

Agrofuel performance is usually presented in terms of GHG emission reductions per unit of energy (gCO_2e/MJ). The first problem with this presentation is that the phrase 'emission reductions' can make consumers think that as soon as they consume agrofuels, they reduce their GHG emissions. However, GHG emissions may only actually be reduced compared to the use of the same amount of energy in the form of fossil fuels. Agrofuel use does lead to GHG emissions, but maybe in smaller amount than transport fossil fuels. If consumers increase their transport energy consumption, they can eventually increase their GHG emissions from transport (cf. rebound effect in section 4.3.9.1).

Another issue with this presentation is that it usually gives an impression of very good understanding due to its precision. For instance, according to the EU RED, OSR agrodiesel leads to 38% GHG emission reduction compared with fossil diesel, just above the 35% threshold (European Commission, 2009a). But such a default value does not take account of the very large disparities in RME GHG emissions due to the widely different farming practices all over Europe. Moreover, there is no acknowledgement of all the methodological bias that was needed to obtain such a figure (energy allocation, choice of N_2O emission factor, etc.) and no mention that iLUC GHG emissions are ignored. The false impression of precision and the lack of acknowledgement of uncertainties are in our opinion very deleterious to the credibility of the scheme.

Moreover, as soon as GHG emission reductions are written down, they give the impression that GHG emission reductions are known for good and that nothing can make them change, even though science in GHG emission calculation and understanding of impact on climate change is probably still in its infancy.

The choice of the functional unit can also lead to a very different view on the classification of agrofuels according to their expected GHG emission reductions. The functional unit used in agrofuel LCAs is usually gCO_2e/MJ of agrofuel. However, at certain blends, agrofuels are more efficient than fossil fuels (for instance the E5 blend – 5% ethanol, 95% petrol – enables to drive a slightly longer car distance than pure petrol). Therefore, some suggest that the functional unit should be related to the real service provided by agrofuels - car driving - and should thus be expressed in gCO_2e/km for specified cars (Cherubini *et al.*, 2009; Gnansounou *et al.*, 2009).
Some even advocate for a functional unit that is not related to end use but to the origins of the feedstock. For instance, the functional unit could be gCO_2e/ha of land cultivated for agrofuel feedstock production, which would stress the importance of land-use efficiency for GHG

mitigation (Larson, 2006) and thus partly acknowledge the importance of iLUC GHG emissions.

To enable comparison, agrofuels' GHG performances should be expressed with an intensive parameter, that is to say a parameter that does not depend on the amount of agrofuel for which it is measured (for instance mass is an extensive quantity whereas density is an intensive quantity). However, although the units gCO_2e/MJ, /km or /ha are approximately intensive when direct GHG emissions are taken into account (because the creation of buildings and other infrastructures for marginal agrofuel production is often ignored in LCAs), these units are no longer intensive when indirect GHG emissions are taken into account.

Indeed, when agrofuel production expands, this necessarily partly leads to indirect GHG emissions. Thus, marginal quantities of agrofuels (whether they are measured in terms of energy - MJ - or in vehicle-kilometre, or in terms of land area needed) will produce more GHG emissions, due to indirect land-use change they are causing. This is why indirect GHG emissions are important to take into account and also why dynamic values of GHG emissions are more interesting than static values.

The presentation of agrofuels in regard with their expected GHG emission reduction compared with fossil fuel consumption is also potentially misleading because the references used for the comparison are today's fossil fuels, which might have increasing embodied GHG emissions in the future. Indeed, as readily-available oil is getting increasingly scarce, non-conventional oil fields (such as those of the tar sands) start to be exploited despite the fact their output is more GHG intensive.

With this in mind, one can easily understand that it is tempting for agrofuel promoters to use high reference values for the GHG-intensity of fossil fuels, or at least to make forecast of agrofuel GHG emission reductions taking account of the increasing GHG intensity of fossil fuels ($(S\&T)^2$ Consultants Inc., 2009a). In this way, even if there is no absolute improvement of agrofuels GHG-wise, their GHG-performance will seem to improve because they are compared to increasingly GHG intensive fossil fuels (cf. section 4.2.6 on boundaries).

Moreover, it should be remembered that increasing agrofuel production might lead to a market saturation of certain co-products. These co-products will thus need to be exported, leading to higher GHG costs for their sterilization, packaging and shipping (Edwards *et al.*, 2007a) which will in turn increase agrofuel GHG emissions.

In conclusion, since agrofuels' GHG emissions are not static and are highly dependent on land needs, they should be expressed in absolute terms (rather than GHG emission reductions), and possibly in gCO_2e/ha until iLUC GHG emissions can be thoroughly modelled.

4.2.9 Other uncertainties

Numerous other uncertainties pertain to agrofuels' GHG emission calculations. For instance, there is still a debate on the actual impacts of tillage practices on GHG emissions on the short-term and the long-term (Ball *et al.*, 1999; Mortimer *et al.*, 2008). Moreover, as seen in chapter 3, other indirect GHG emissions (those not linked to iLUC) are not taken into account so far in agrofuel GHG emission methodologies (such as the impact of the change in diet of cattle - due to agrofuel co-products used as animal feed - on methane emissions, cf. chapter 3, section 3.2.7). Finally, there can always be interrogations on the quality and reliability of the data used for calculation in agrofuels' GHG LCAs (Benoist, 2009).

4.3 Some fundamental issues with agrofuels

Certification schemes and agrofuel policies in general tend to support agrofuels for their supposed GHG emission reductions. However, as was seen in section 2 of this chapter, methodological bias encountered in agrofuel GHG LCAs can lead to very different results of expected GHG emissions from agrofuels, with specific agrofuels sometimes even assessed to be more GHG-intensive than fossil fuels.

In addition, there seems to be several fundamental issues that challenge most agrofuels' GHG benefits and even challenge agrofuels' very potential to decrease GHG emissions attributable to the transport sector.

4.3.1 Issues relating to agrofuels being certified and not other biomass

An issue sometimes mentioned as 'game-playing' can happen at the farm level when farmers do whatever is possible to get high yields of agrofuel crop while not attributing to agrofuel crops the environmental burden that arises from such practices.

For instance, a farmer may spray excessive amounts of nitrogen on a crop that precedes agrofuel feedstock cultivation in order to reduce the need for nitrogen for the following agrofuel crop. Thus, the agrofuel feedstock will require less nitrogen fertiliser because N is still in excess in the soil but the cultivation practices of the former crop led to excessive nitrogen use (and thus leaching) causing not only water and air pollution, but also excess N_2O emissions and embodied GHG emissions (Kindred *et al.*, 2008a).

Another issue relates to the fact that most schemes require that agrofuel feedstock cultivations are not made on lands that used to be forests or grasslands after a certain reference date. However, game playing may occur in this case too. For instance an oil palm company may certify all its feedstock that comes from the old enough part of its oil palm plantation for agrodiesel production and put aside the most recent parts of its plantation (the ones that come from recent deforestation) to markets for which LUC criteria are non-existent or not very developed (cosmetics and food for instance). The plantations thus have a very negative overall impact on the environment but the company can still produce certified agrofuels.

Such problems would not happen if biomass production was audited for the whole farm/plantation or if all biomass for whatever use had to follow similar certification criteria.

4.3.2 How to avoid iLUC?

Two scientific papers of main importance in the agrofuel debate were published together in the Science issue of February 2008 (Fargione *et al.*, 2008; Searchinger *et al.*, 2008). Searchinger *et al.* raised the issue of indirect Land-Use Change (iLUC) GHG emissions which had been largely ignored by then and calculated that "maize-based ethanol, instead of producing a 20% savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gases for 167 years" while Fargione *et al.* found that agrofuels' 'carbon debt' could spread over decades when agrofuels' feedstock cultivation was associated with Land-Use Change (LUC).

Following the introduction of these new elements raising doubts on agrofuels' GHG emission benefits, the EEA (European Environment Agency) Scientific Committee asked for a suspension of the 10% agrofuel target of the EU (EEA Scientific Committee, 2008). In parallel, the UK launched the 'Gallagher review' on indirect impacts of agrofuels which recommended in July 2008 to reduce the UK agrofuel blending targets due to uncertainty on agrofuels' indirect environmental impacts (RFA, 2008b). As a consequence, the UK Government reduced the initial 5% (by volume) target of agrofuel blend for 2010-2011 to 3.5% (by volume) on April 15th, 2009. The Netherlands followed the same line in November 2008 (target of 4% agrofuels by 2010 instead of 5.75%) (Flach, 2008) while Germany reduced its agrofuel incorporation targets as well as agrofuels' tax incentives in October 2008 (The Bioenergy Site, 2009).

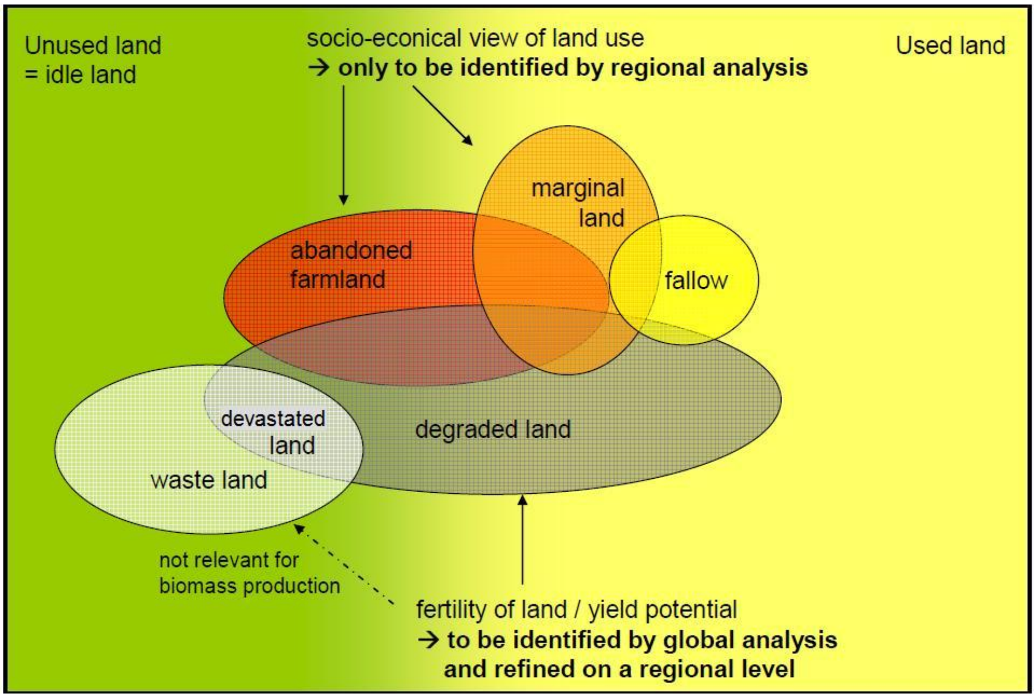
Although some certification schemes seem to understand the importance of iLUC and take it into account in their GHG emission calculations (especially the American LCFS - in theory - and at some point the RFS schemes, despite controversies, cf. 4.1.3), most schemes still ignore iLUC in their criteria or only favour some fuels that they think are less likely to cause iLUC.

4.3.2.1 Agrofuels made of feedstocks from abandoned agricultural land or marginal land

According to the definition provided by the RED, 'degraded lands' are severely degraded lands and heavily contaminated lands that were not in use for agriculture or any other activity in January 2008 (European Commission, 2009a). With this Directive, agrofuels made from feedstocks grown on 'restored degraded land' benefit from a 29 gCO_2e/MJ bonus, which means that agrofuels whose crops have been grown on 'restored degraded land' are not expected to reach as stringent a threshold as other agrofuels.

This idea that degraded land could be used for agrofuel feedstock production can also be found in Wicke's paper on palm oil production systems for energy purposes which concludes that "in order for […] biodiesel to be sustainably produced from palm oil and its derivatives, only degraded land should be used for palm oil production" (Wicke *et al.*, 2008). However, there are different categories of degraded land (cf. figure below), some of which are already in use (parts of fallow land and marginal land to some extent) and some of which might not be interesting for biomass production (especially 'devastated land').

Figure 51: Methodological approach to identify land categories and their relationship



Source: Adapted from Wiegmann (2008)

It should be noted that whereas Wiegmann *et al.* define ‘idle land’ as any unused land including natural ecosystems such as rainforest (Wiegmann *et al.*, 2008), the Renewable Fuels Agency more carefully views ‘idle land’ as a land with no significant carbon stock, little conservation value and the use of which does not violate local people’s rights (RFA, 2008b).

Abandoned farmlands may look like a good option to avoid iLUC but the amount of such land with sufficient productivity for the cultivation to be economically-viable might not be adequate for agrofuel production at the global scale. Indeed, Campbell *et al.* determined that the global potential of bioenergy (of which agrofuels are only a portion) from abandoned agricultural land could only enable us to meet less than 8% of the current world primary energy demand, partly because there is not as much land available as previously thought but also because available land is not very productive (Campbell *et al.*, 2008). As a matter of fact, abandoned agricultural lands have often been abandoned for sound economic reasons relating at least in part to poor productivity.

Another option may be to grow agrofuel feedstocks on degraded waste land such as *Imperata* grasslands in Indonesia. *Imperata cylindrica* (or alang-alang grass) is a grass that sometimes grows on lands that have been deforested through burning before being used as agriculture lands. This grass eventually makes these lands develop into waste lands and prevents them from developing naturally into secondary forest (Reinhardt *et al.*, 2007). Since restoring *imperata* grasslands and converting them into oil palm plantations might help increase carbon stocks, the RFA plans to introduce an option for agrofuel suppliers to report on similar projects that would significantly reduce risks of iLUC (RFA, 2010d).

However, the use of such areas for agrofuel production may not be the optimum use environmentally-wise. Indeed, since reforestation has been shown to bring more GHG emission reductions than agrofuel production (Righelato & Spracklen, 2007), the restoration of degraded land for palm oil agrodiesel production may look more like a justification of palm oil than a real attempt to decrease GHG emissions.

Finally, a hardy shrubby tree producing oil-rich fruits called *jatropha curcas L.* is sometimes presented as a readily-available ‘sustainable’ agrodiesel feedstock (Cormack, 2008). Since its fruits are toxic, some claim that jatropha does not compete with food and thus does not cause iLUC (cf. chapter 2 section 2.1). This is not a good argument because jatropha needs to be planted on agricultural land to get significant yields. Therefore jatropha competes with food production. Actually, jatropha plantations directly displacing food crops have already been observed in India and the Philippines (Luoma, 2009).

Despite the claims of some jatropha promoters stating that jatropha would easily grow on most degraded lands (Cormack, 2008), would require very little agrochemical input as well as little water to generate oil-rich seeds whose oil can be extracted for agrodiesel production[32], it seems that when jatropha grows on marginal land, it does not produce much oil (Wiggins *et al.*, 2008; Luoma, 2009). Jatropha thus appears to be far from the wonder crop that it is sometimes claimed to be.

The conclusions of a recent German report leave little doubt on the misrepresentation of jatropha as a wonder crop (Endelevu Energy *et al.*, 2009):

> *"The results of this survey […] show* ***extremely low yields and generally uneconomical costs of production****. […] Jatropha currently does not appear to be economically viable for smallholder farming when grown either within a monoculture or intercrop plantation model.*
> *The only model for growing Jatropha that makes economic sense for smallholders […] is growing it as a natural or live fence with very few inputs. […]*
> *Therefore, we recommend that all stakeholders carefully reevaluate their current activities promoting Jatropha as a promising bioenergy feedstock.* ***We also suggest that all public and private sector actors for the time being cease promoting the crop among smallholder farmers for any plantation other than as a fence****."*

4.3.2.2 Agrofuels made from wastes and residues

To show its support of agrofuels that have little risk of causing iLUC, the article 21 paragraph 2 of the EU RED states that the contribution of "biofuels produced from wastes, residues, non-food cellulosic material, and ligno-cellulosic material shall be considered to be twice that made by other biofuels" (European Commission, 2009a).

Indeed, these fuels are often thought to generate no or very little iLUC:
- wastes such as used cooking oil are thought not to compete with food;
- 2nd-generation agrofuel feedstocks (crop residues, non-food cellulosic material, and cellulosic material) are often thought not to compete with food production neither.

However, the wording 'waste' can be confusing in that those who do not see the use of a product might intuitively consider it as a waste when this product actually has a use.

[32] Cf. http://www.d1plc.com

Notwithstanding, the point that waste is treated as a product in law, a report performed for the RFA studied indirect effects of several “wastes, residues, and by-products” of agrofuels, namely molasses, Municipal Solid Waste (MSW), straw and tallow, without distinguishing the categories they belonged to even though these products are very different in terms of their use (Brander *et al.*, 2009). In this list, only MSW can in certain conditions be seen as a ‘waste’ (when nothing is done with MSW apart from storing it in landfills). Molasses which are a by-product of sugar production have different uses including animal feed; straw can be ploughed back into soils, bailed or used as animal bedding; finally tallow can be burnt to produce heat or be used in pet foods for instance. The conclusions of this report are that “wastes, residues, and by-products” can generate negative indirect GHG emissions when they already have a high degree of utilisation. This conclusion is probably precisely the reason why the European Directive promotes the use of ‘wastes’ rather than by-products for biofuel production.

It should be noted that although used cooking oil may seem as a good agrofuel in that it truly is a waste in most cases (disposed of by restaurants either in waste reception centres or directly in sinks [sic]) and thus has virtually no negative indirect effect (even though some might burn used cooking oil for energy production?), it has a very low potential compared to the world transport fuel energy demand. Thus it is only really interesting at very local individual scales.

Finally, the use of Used Cooking Oil as a fuel can somehow give legitimacy to restaurants not necessarily promoting healthy lifestyles but that sometimes want to appear green in order to improve their image even though their activities lead to much worse environmental impacts (Amazon deforestation according to Greenpeace (Butler, 2006)) than those avoided thanks to the use of recycled cooking oil (McElroy, 2007) (cf. figure below).

Figure 52: Advertisement for McDonald's trucks running on recycled cooking oil

Source: (McElroy, 2007)

The use of crop residues for 2nd-generation agrofuel generation agrofuels also seems at first sight like an interesting option in order to limit risks of iLUC. However, the removal of crop residues may exacerbate soil degradation, reduce land productivity and thus aggravate food insecurity (Lal, 2008). This point will not be developed further as it is linked to '2nd-gerneration biofuels' that rely on a technology that is not viable to date.

4.3.2.3 Increase yields

Another idea to avoid iLUC is to increase yields of agrofuel crops and crops in general so that the need for agricultural land for biomass production (food + feed + fuel + fibre, etc.) does not increase. Agricultural yields are sometimes expected to increase thanks to different methods:

- intensification of agriculture;
- reduced crop rotation;
- use of GMOs.

However, such strategies aiming at increasing yields may lead to numerous environmental issues:

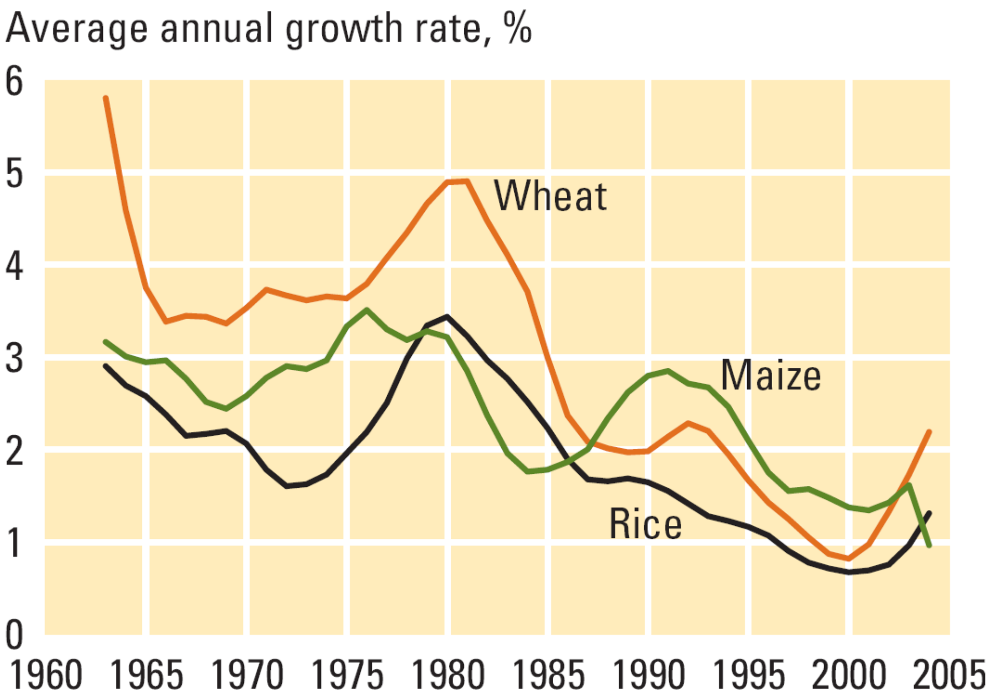
- intensified agriculture generally requires more N fertilisers and thus leads to more N_2O emissions (Dorin & Gitz, 2008). Agriculture intensification also leads to higher environmental impacts such as increased soil degradation, loss of biodiversity, water pollution, etc. (Salmon, 2008) and eventually soil exhaustion which in turn leads to decreases in yields (in the case of lands already under very intensive farming practices);
- reduced crop rotation might lead to increased needs in pesticides and even to decrease in yields (Salmon, 2008);
- despite claims that GMOs will enable large increases in yields (Calabotta, 2009; Sheehan, 2009), on top of the unintended negative consequences on ecosystems they may have, there is little evidence that GMOs enable any yield increase at all (Gurian-Sherman, 2009).

There are currently ideas within the bioenergy sector for intensifying agriculture in ways that would not harm the environment. For instance, the integration of agrofuel crop cultivation with cattle might produce extra amounts of animal feed (for instance hydrolysed bagasse from sugarcane) while keeping the same amount of land and thus prevent iLUC (Dehue *et al.*, 2010; RFA, 2010d).

A similar idea is contained in the concept of 'closed-loop systems' in which agrofuels produced would not compete with food production (Jamieson, 2008). Such systems rely on an optimal use of biomass thanks to livestock, which apparently improves overall efficiency of land use and generates 'biogas' at the same time (biogas is not readily usable in today's most common car engines and thus outside the subject of this thesis). Even though closed-loop systems seem in appearance to be promising at least at the small scale, they have been little studied and there is no wide understanding of their reach and the reality of their effectiveness.

Some might hope that increasing agrofuel production will not lead to iLUC because crop yields will sufficiently increase at the world level. However, there is a prevailing tendency for yields to either stabilise in 'developed' countries or for the growth of yields to decrease in 'developing' countries (cf. figure below):

Figure 53: Evolution of the average growth rates of yields for major cereals in 'developing' countries



Source: (World Bank, 2007)

It should be noted that there certainly are possibilities to considerably increase yields in an environmentally-friendly way in some 'developing' countries but this must be done with great care and with consideration to local ecosystems.

4.3.2.4 Use crops with the highest yield of agrofuel per hectare

Crops with the highest net outputs of agrofuel per hectare, taking account of co-products, lead to the lowest amount of iLUC (Croezen & Brouwer, 2008).

Thus some compare agrofuels' feedstocks according to the volume of agrofuel and the relative amount of energy produced from one 1 ha of land (The Royal Society, 2008) while some advocate a comparison of agrofuels in terms of gCO_2e/ha (Larson, 2006).

The idea that crops leading to the lowest output of agrofuel per hectare cause the most iLUC appears in Fritsche's results of iLUC factors (cf. section 4.2.6) with sugarcane and palm oil having the smallest iLUC factors despite such crops being located in areas subject to iLUC (Fritsche *et al.*, 2009).

However these results can be difficult to accept in that such crops are the most directly linked to LUC and iLUC (deforestation or ploughing up of grassland occur near the regions of sugarcane and palm oil cultivation) while EU and US crops are less directly linked to iLUC (because there is little LUC occurring in Europe and in the US). However, **at the global scale, EU and US agrofuel crops might be the ones that lead to most iLUC**.

4.3.2.5 Change consumer behaviour

Another option to avoid iLUC - that is to our opinion not sufficiently mentioned – is to change consumer behaviour.

First, the most obvious way to decrease iLUC from agrofuels is to decrease agrofuel production. However, in a fossil-fuel constrained world with growing GHG emissions despite climate change threats, such an option does not seem suitable before truly low-carbon electricity is available at a sufficiently large scale for efficient electric cars.

Then, the most acceptable way to decrease risks of iLUC from agrofuels on the consumer side is to reduce overall pressure on land for instance by avoiding or decreasing the consumption of land-intensive products.

Since meat (especially beef) and dairy (especially butter and cheese) are among the most land-intensive types of food (cf. table below), a shift from a vegetarian diet (in 'developing' countries) to an affluent diet with meat leads to a tripling of the land requirement (Gerbens-Leenes & Nonhebel, 2005). At the same time, a 25% decrease in meat consumption in 'developed' countries combined with less food wastage would lead to a decrease of agricultural land need of about 15% compared with current agricultural land (Wirsenius *et al.*, 2010).

Table 23: Land requirement for selected food with large consumption (in m^2 year kg^{-1})

	Land requirement (m^2 year kg^{-1})
Meat	
Beef	20.9
Pork	8.9
Chicken filet	7.3
Milk products and eggs	
Whole milk	1.2
Semi-skimmed milk	0.9
Butter	13.8
Cheese	10.2
Eggs	3.5
Cereals, sugar, potatoes, vegetables and fruits	
Cereals	1.4
Sugar	1.2
Potatoes	0.2
Vegetables (average)	0.3
Fruits (average)	0.5

Source: Adapted from Gerbens-Leenes & Nonhebel (2005)

Thus, eating less meat at the global scale might enable us to free up large amounts of pasture and cropland (Stehfest *et al.*, 2008) as well as improving human health since diets avoiding animal products (vegetarianism and especially veganism) appear to be the healthiest in the long-term (Campbell, 2006). The newly freed grassland and cropland could partly be used for natural vegetation regrowth and carbon uptake (helping reduce net anthropogenic GHG emissions) while other parts could be used for bioenergy production. In such a situation, agrofuel production would not lead to iLUC (unless maybe if one compares this scenario with a scenario of 100% vegetation regrowth on freed lands).

According to Bergsma, one vegetarian day per week can compensate for iLUC related to the agrofuel imports needed to achieve the 5.75% agrofuel target of the EU agrofuels Directives. Thus, according to him “a meat tax may be the most solid way to compensate iLUC effects of biofuels” (Bergsma, 2008).

Moreover, livestock are considered as one of the most important sources of GHG emissions, generating from 18% (Steinfeld *et al.*, 2006) to as much as 51% global anthropogenic GHG emissions (Goodland & Anhang, 2009). Therefore, a decrease in animal products consumption will not only decrease pressure on land and potential iLUC from agrofuels but also significantly decrease GHG emissions in general.

Finally, on top of GHG emissions, livestock also generate considerable adverse environmental impacts among which air pollution, land, soil and water degradation and the reduction of biodiversity (Steinfeld *et al.*, 2006). Therefore, while decreasing animal product consumption might be a good way to reduce iLUC from agrofuels, it would actually be beneficial to the environment in a lot of ways.

Paradoxically, it should be noted that agrofuel production today largely relies on livestock. Indeed, agrofuel by-products such as DDGS, rapemeal and sugar beet pulp often help making agrofuels commercially viable as well as enable agrofuels to have positive direct GHG benefits (because in the substitution approach, a certain amount of the agrofuel chain GHG emissions are attributed to these by-products since they are supposed to replace other animal feeds that would have needed to be produced otherwise).

In a way, agrofuels not only rely on animal farming but may also promote them (by decreasing animal feed prices). Actually, such co-products even promote factory farming or at least animal farming where animals are fed with highly processed food rather than natural readily-available food, which raises ethical questions as well as questions related to the nutritional interest of such animal products (cereal-fed cattle show unhealthy lipid profiles, particularly higher Omega-6 /Omega-3 ratios compared with grass-fed cattle (Pelletier, 2007; Kraft *et al.*, 2008; Duckett *et al.*, 2009)).

4.3.3 Straight vegetable oil

Though straight vegetable oil (SVO) is not particularly promoted by agrofuel certification schemes, some have presented SVO as a wonder agrofuel in that it does not require complex technologies, is easily available at small scale and causes less direct GHG emissions than agrodiesel (from the same vegetable oil) because there is no need for transesterification with fossil methanol (Lubraniécki, 2005).

However, the production of straight vegetable oil has the same consequences as agrodiesel iLUC-wise unless the oil is produced from truly unused land and thus does not compete with other biomass uses or comes from feedstocks that have no use otherwise. This can be the case, for instance, for jatropha oil when jatropha is primarily used as a natural fence and produces fruits that are not used. Such a jatropha oil then has very little indirect impact because it does not compete with any other use (apart from maybe the soil getting nutrients from decaying jatropha fruits – the importance of this should thus be evaluated).

4.3.4 Incentive not to change and emission of questionable signals

Even though agrofuel certification schemes might present some interesting environmental safeguards for agrofuel production (at least on some direct environmental consequences of agrofuel production), most agrofuel certification schemes focus on 1st generation agrofuels and often legitimise intensive industrial farming practices since such practices fit in their ‘sustainability criteria’. Therefore, agrofuel certification can be seen as a promoter of technology lock-in in terms of technology of engines that use agrofuels as well as in terms of technology for the production of agrofuel crops.

Then, agrofuel certifications say nothing about the consumer side of the story. Consumers are not encouraged to decrease their transport energy consumption or to decrease their consumption of land-intensive products such as meat. Thus, agrofuel certification can be viewed as a promoter of behaviour lock-in too.

It is interesting to consider that every time someone buys a product, he or she implicitly supports the production of the product and the way it was produced. There comes the question as to what kind of signals the purchase of agrofuels currently sends. In today’s world, as was seen previously, buying agrofuels at first sight supports changes from an oil-based society to a low-carbon society. However, due to all the environmental implications of agrofuels, the signals sent by agrofuels purchase appear much more questionable:

- support for industrial farming leading to erosion, water, soil and air pollution, etc.;
- support for fertiliser production from natural gas and for pesticide production as well as for the factories that produce fertilisers and pesticides;
- sometimes support to GMOs (some certification schemes agree in principle with GMOs if they prove to be ‘beneficial’);
- support to meat and dairy production since many agrofuel by-products make more economic sense when they are used as animal feed;
- but also support to car production – and car plant construction, road construction, etc. (cf. figure 20 in section 3.1.2.3).

Moreover, in order to decrease iLUC, the technology fixes commonly mentioned are based on the intensification of meat production, with animals merely seen in terms of potential gains of efficiency in digesting agrofuel by-products (Croezen & Brouwer, 2008). Such reports clearly seem to legitimise meat and dairy factories.

Unless consumer behaviour changes, agrofuels’ increasing consumption makes it nearly compulsory to enter into a logic of increase in agriculture output by what are apparent illogical means, whether it is through an increase in agricultural yields (not necessarily sustainable – for instance, US maize ethanol is sometimes nicknamed 'Monsanto moonshine', cf. chapter 3) or an increase in arable land area at the expense of grasslands, forests or other ecosystems.

Finally, in a paradoxical way, the increase in agrofuel production might lead to a decrease in oil prices, or at least a delay in the increase in oil prices. Thus, agrofuel production could encourage oil consumption.

4.3.5 Better uses of biomass

According to Edwards *et al.*, "the conversion of biomass into conventional [agro]fuels is not energy-efficient [in that] ethanol and [agro]diesel require more [agro]energy than the fossil energy they save" (EUCAR *et al.*, 2007).

It seems that from an energy-efficiency as well as a GHG emission reduction perspective, it would be much more efficient to use land for biomass for 'bio-electricity' production rather than for 'liquid biofuel' production. Indeed, considering the higher productivity per hectare of switchgrass (for 2^{nd}-generation agrofuels production or electricity generation) - thus the lower risk of iLUC and its related GHG emissions - and the higher efficiency of electric vehicles, Campbell *et al.* find that one unit of area gives better GHG emission results for the end transport energy unit used when it is planted with switchgrass used for electricity generation than when it is planted with switchgrass or maize for ethanol production (Campbell *et al.*, 2009). However, Campbell *et al.* also warn that the development of electric vehicle could at the same time be an incentive for coal-generated electricity and thus call for a caution in the use of their results.

4.3.6 Better ways to reduce GHG emissions from the transport sector

Biomass might be more efficiently used for transport energy generation GHG-wise than by producing agrofuels. However, there are simple ways to reduce GHG emissions from transport that require minimum education.

For instance, the website ecodrive.org presents 5 golden rules of 'ecodriving' (Wilbers, 2006):

- shift up as soon as possible;
- maintain a steady speed;
- anticipate traffic flow;
- decelerate smoothly;
- check the tyre pressure frequently.

Such 'ecodriving' practices could result in GHG emission reductions of as much as 10% (OECD/ITF, 2008).

In addition, the French Ministry of Agriculture presented in a 2007 paper an assessment of the potential reduction in the use of oil in transport by 2020, the figures of which are in the following table:

Table 24: Measures to reduce oil consumption at the European level

Measure	Million tonnes of oil consumption avoided
Reduction of speed limits	11
Use of tyres that reduce fuel consumption	15
Higher fuel prices	22
More stringent emission limits for new vehicles	28
More energy-efficient energy conditioning systems	1
More efficient lubricants	4
Decrease in travelled distance by light duty vehicles	5
Decrease in travelled distance by cars	20
Development of agrofuels	**43**

Source: Adapted from Ministère de l'Agriculture et de la Pêche (2007)

This table shows that measures other than agrofuel promotion can enable large reductions in oil demand and thus substantial reductions in GHG emissions from transport (whereas there is no certainty that agrofuels actually provide GHG emission reductions). Up until now, apart from some considerations expressed during the development of the Californian LCFS (Air Resources Board, 2009), few agrofuel certification schemes have worked on these points, which would however merit to be coupled with an agrofuel certification.

4.3.7 The bigger picture: can agrofuels be sustainable in the current context?

This last part of the present chapter aims at contextualising agrofuels within the 'bigger picture', that is the current context of world transport fuel consumption.

4.3.7.1 Do agrofuels really substitute for fossil fuels?

Agrofuels are often said to be substitutes for fossil fuels for transport. Indeed, at a consumer level, one that consumes a portion of agrofuels instead of fossil fuels can say that he/she substituted fossil fuels for agrofuels. But this simple image can be misleading and has little interest when considering national and global scales.

4.3.7.1.1 Rebound effect

It has been observed that while the energy efficiency of new cars has dramatically improved during recent years in some countries, the fossil fuel demand for transport has not decreased as much as expected. One explanation to this paradox is that "lower fuel costs associated with more efficient cars [can] encourage drivers to drive more" (Gross *et al.*, 2009), a phenomenon known as '**positive rebound effect**' (Dimitropoulos & Sorrell, 2006).

Negative rebound effect also happens when, for instance, people realise that they want to change their behaviour, thus change their car for one that is more energy-efficient AND decrease the use of their car. Indeed, it has been noticed that environmentally-friendly behaviours have a tendency to spill over into other behavioural domains (Thøgersen & Ölander, 2003).

Similar phenomena can happen with agrofuel consumers. In the case of a positive rebound effect associated with agrofuels, a person buys agrofuels in preference to fossil fuels following environmental considerations (accepting the mainstream commercial argument that agrofuels help preserve the planet), then he or she can feel better and thus drive more. But such positive rebound effect can eventually lead to a higher consumption of fossil fuels.

Indeed, take the example of Mr. X who drove an average 20,000 km (thus consumed 20,000 units of energy) per year on 100% fossil fuels and then "does the right thing", buys agrofuels (blended) and drives 25,000 km (and consume 25,000 units of energy). If we assume that 10% by energy content of his fuel are agrofuels, then he uses 10% x 25,000 = 2,500 units of energy from agrofuels for driving. Does this new consumption of 2,500 units of agrofuels substitute for fossil fuels? Not really, because 25,000 - 2,500 = 22,500 units of energy from fossil fuels are now used, which is 22,500 - 20,000 = 2,500 more units of energy from fossil fuels than before.

In this case, there is a positive rebound effect, resulting in an increased consumption of agrofuels (0 to 2,500 units) AND fossil fuels (20,000 to 22,500). Thus agrofuels do not substitute for fossil fuels but add to fossil fuels (one could actually say that agrofuels substitute for the supplementary fossil fuels that would have been consumed were there no agrofuels available).

Mr. X could also drive the same amount of km with his car and thus actually reduce his (direct) fossil fuel consumption for road transport but he can then be tempted to fly more for holidays, because he feels like he already did 'his bit' for the environment and is thus 'allowed' to enjoy plane travelling, which is another form of positive rebound effect.

Luckily, Mr. X can also be conscious about the environmental impacts of fossil fuels but also about the environmental impacts of agrofuels, and thus decide to consume less total transport fuels, drive less and find alternative means of transport, resulting in a lower overall environmental impact (negative rebound effect).

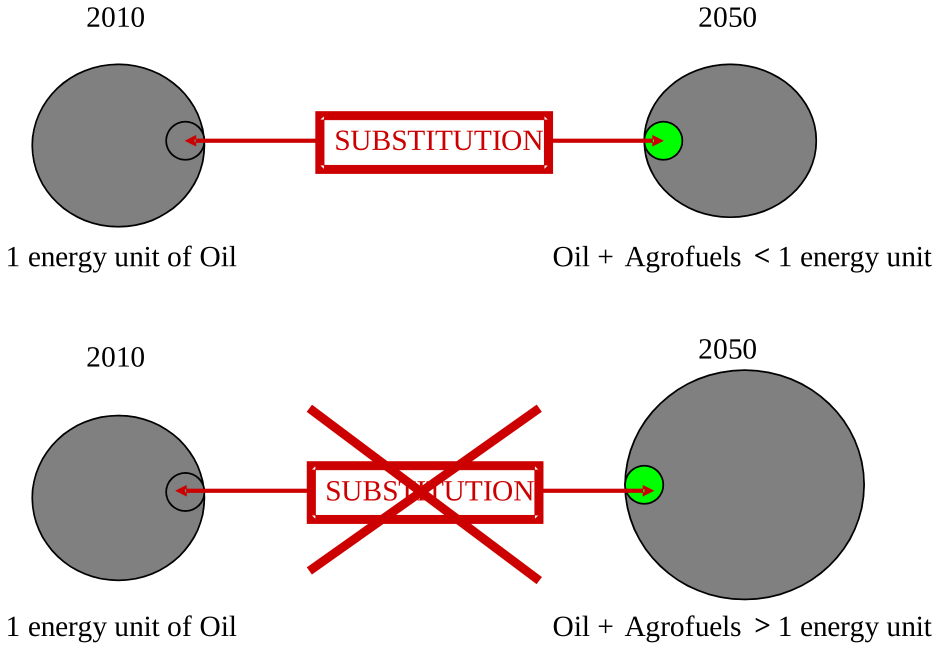
In short, agrofuels substitute for fossil fuels only when total fuel consumption stays the same or decreases. If total fuel consumption increases, then agrofuels add to fossil fuels.

4.3.7.1.2 Evolution of the share of agrofuels in world transport energy demand

In 'developed countries', there is a tendency towards stagnation of transport energy demand. Therefore, one could say that agrofuels substitute for fossil fuels in 'developed countries'.
However, matters are different at the world level since many 'developing countries' aim at following the Western carbon-intensive model of civilisation. Therefore, at the world level, energy consumption currently increases.
Thus, can we still say, at the world level, that agrofuels are a substitute to fossil fuels?

The following figure (fossil fuels in grey and agrofuels in green) shows that, as indicated with our individual Mr. X example, although one can talk about substitution when the total consumption stays the same or decreases, one cannot use the word 'substitution' when total consumption actually increases.

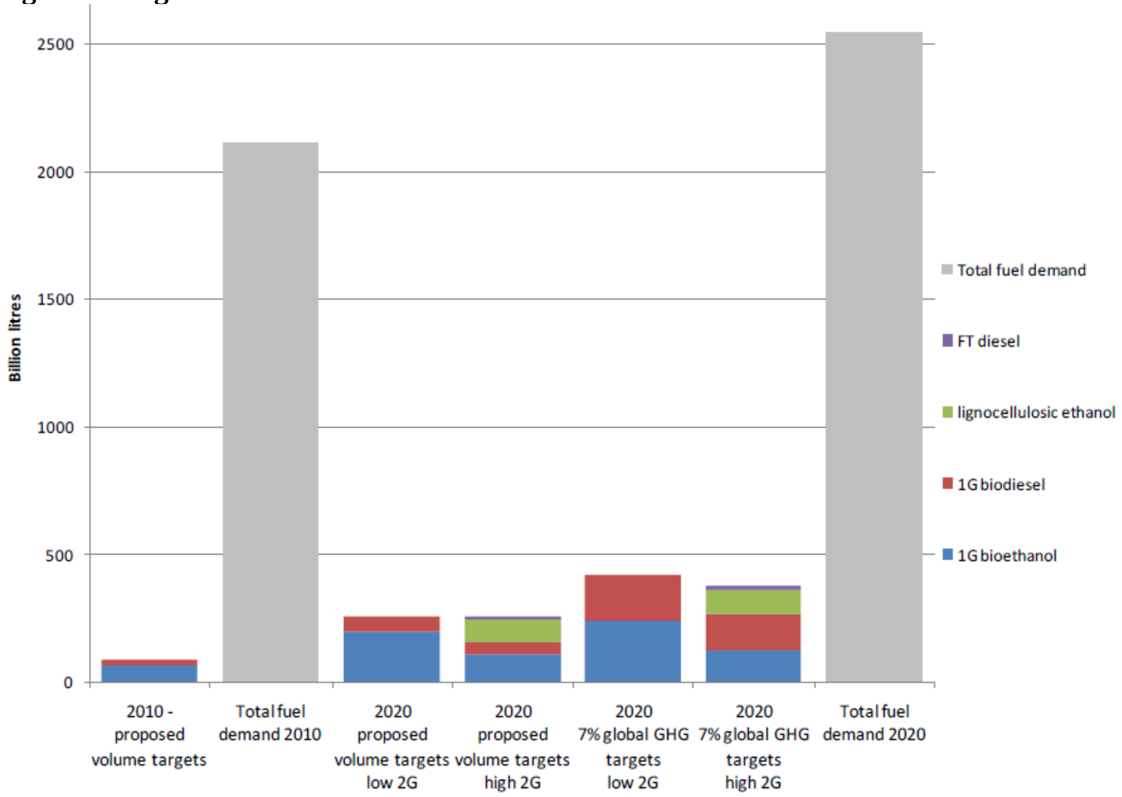
Figure 54: Substitution or addition?



Source: Personal figure

When looking at the scenarios developed by E4Tech (2008c), it appears that the scenario with the highest increase in agrofuel demand between 2010 and 2020 will not enable one to compensate for the expected increase in the demand for total transport fuels (fossil fuels + agrofuels) by volume. Since the scenarios express fuel demand by volume and since agrofuels have a lower LHV than fossil fuels the situation is even worse with respect to energy content. Thus, the 2020 consumption of fossil fuels (by volume but also by energy content) will be higher than that of 2010 even for the most optimistic increase in agrofuel consumption. Therefore, at the global level agrofuels will not substitute for fossil fuels but will simply add to the increase in fossil fuel demand. This can be viewed in the following graph:

Figure 55: Agrofuel demand in different scenarios



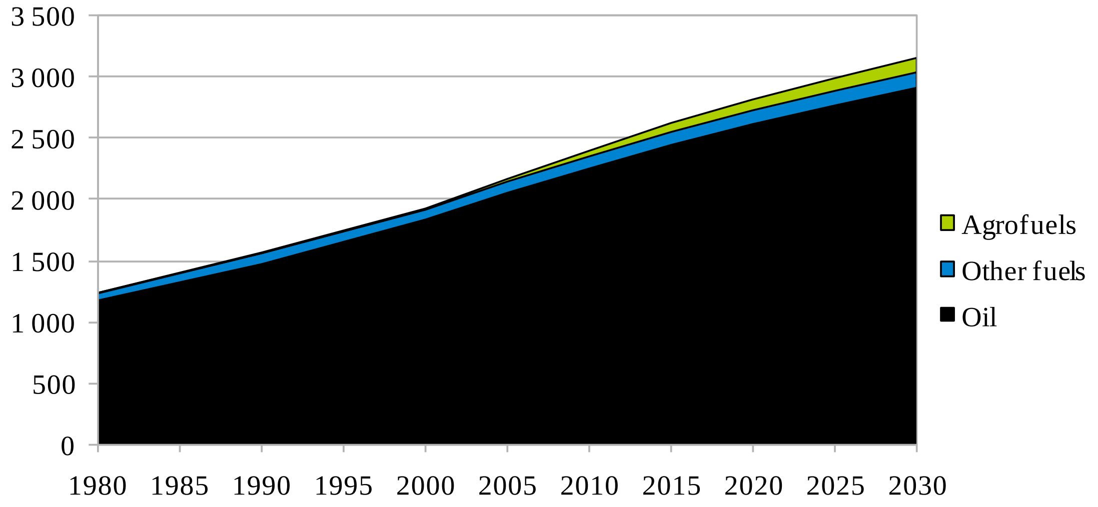
Source: Adapted from E4Tech (2008c)

4.3.7.2 Can agrofuels bring any reduction in transport GHG emissions?

The International Energy Agency (IEA, 2006; 2007; 2008) also developed scenarios on the evolution of transport fuels consumption but even when the consumption of agrofuels largely increases it is never sufficient to compensate for the increase in oil consumption for transport.

For instance, according to the reference scenario of the World Energy Outlook 2008 (WEO 2008), there would be an increase by 2,915 - 2,105 = 910 Mtoe in oil consumption for transport between 2006 and 2030 while at the same time agrofuel consumption would only increase by 118 – 24 = 94 Mtoe, which is nearly 10 times less. This can be seen in the graph below for a better understanding of the situation:

Figure 56: Evolution of world transport energy demand in Mtoe



Source: Personal graph made with data from WEO 2008 (IEA, 2008)

This graph encompasses all transport modes (road, air, water), but even though agrofuels will probably largely be consumed for road transport, it seems that road transport will remain by far the main consumer of transport energy among transport sectors (IEA/WBCSD, 2004).

With this graph in mind, one can clearly see that agrofuels cannot make transport more sustainable, simply because transport energy demand will increase if no serious policy for energy demand reduction (taking account of rebound effect) is put in place, at the world level. It is a sobering reminder that evidence of world-level agreement to address energy demand is scarce by reference to the evolution of the Climate Change Convention and the Kyoto Protocol over the past twenty years.

One could say that agrofuels nevertheless enable some GHG emission reduction compared to 100% fossil fuel scenarios. This may be true, but:

- climate change requires rapid action and GHG emission reductions compared to **now**, not compared to in 10 or 20 years time;
- when indirect GHG emissions are taken into account, there is no certainty that agrofuels deliver any GHG benefit compared with fossil fuels.

As can be seen from the discussion above, reference scenarios forecast that transport fossil fuel demand will increase. Thus transport-related GHG emissions will increase too, even with best theoretical truly carbon-neutral agrofuels. To sum up, even with current aggressive policies promoting agrofuels in Western countries, global GHG emissions from transport are likely to increase.

4.3.7.3 Can agrofuels be sustainable?

All this brings us back to the question: “can agrofuels be sustainable from an environmental point of view?”

It seems that a product itself cannot be said environmentally sustainable *per se* but its use or the policy surrounding the consumption of this product can eventually be sustainable. Thus, for agrofuels, only the globally averaged evolution of fuel transport energy mix could potentially be said sustainable, rather than agrofuels themselves.

The evolution of transport energy demand would be sustainable if the demand for fossil transport fuels was decreasing (eventually reaching zero in theory, or at least the portion of the planet’s carrying capacity assigned to transport), and if agrofuels substituting for fossil fuels (‘substitute’ is the right verb in this sentence because total transport energy demand would be decreasing) were carbon-neutral (all direct AND indirect GHG emissions being taken into account) or under the portion of the planet’s carrying capacity assigned to transport agrofuels.

In today’s world, first-generation average agrofuels are far from being carbon-neutral, they add to increasing transport fossil fuel energy demand (rather than substitute for fossil fuel), and the growing of their feedstocks’ land need is a worrying extra pressure on increasingly sought-after arable land.

Moreover, certification schemes do not seem to be able to prevent indirect GHG emissions related to agrofuels from occurring. Finally, such schemes are not intended to decrease world transport energy demand and can even be seen as an incentive in Western countries not to change people’s transport behaviour.

Therefore, current transport agrofuels in the current context of transport energy demand and land demand **cannot be said to be sustainable.**

Figure 57: Demonstration against agrofuels

Source : http://archive.corporateeurope.org/sra.html

Relevant transport policies should first of all aim at decreasing the transport energy demand as well as decreasing arable land demand (because as we have seen, land and energy are very closely linked with first-generation agrofuels). Such policy options do not rely on such large methodological uncertainty, guesswork and political bias as agrofuels' promotion does. In this regard, changing consumer behaviour seems to be a much more worthy measure for law and policy makers to invest in for broader 'sustainability' reasons.

Only when agrofuels truly start to substitute for fossil fuels at the world level (that is to say when global transport energy demand decreases), when their production does not lead to any displacement (and thus iLUC GHG emissions) and their production results in little direct GHG emissions (that is to say the amount of emissions that could be attributed to average transport fuels regarding the planet's carrying capacity), then agrofuels' use could be said to be sustainable. It seems that we are a long way from living in such a world and from having such agrofuels at our disposal.

Thus, claims of 'sustainable' agrofuels look like marketing tools, or ways to make people believe that agrofuels can be fuels with low environmental impacts, which they are not.

Conclusion

This chapter demonstrated that agrofuels' environmental certification schemes generally focus on GHG emissions but largely neglect other environmental areas of concern, for which criteria and principles are rather vague and probably not stringent enough to prevent negative environmental impacts from occurring. It also appears that secondary and tertiary environmental impacts are totally ignored, the **focus being made on direct primary environmental impacts**. As for iLUC environmental impacts, only those related to GHG emissions are mentioned but thus far ignored by most certification schemes (apart from the LCFS). Finally, it was shown that indirect impacts other than iLUC GHG emissions are not even mentioned by certification schemes. Thus, the range of impacts taken into account by certification schemes is very limited and cannot give a relevant image of agrofuels' actual environmental impacts.

Moreover, results from LCAs used by certification schemes for the evaluation of GHG emissions were shown to be highly dependent on hypotheses (such as allocation rules, baseline and boundaries, choice of duration for annualisation, emission factor for N_2O, etc.), which make this tool highly biased and subjective.

Since current certification schemes only capture a small part of environmental impacts and since their flagship tool - LCA - is necessarily biased (usually in a way that is favourable to agrofuels) there is a general oversimplification **- which is not recognised -** of the perception of agrofuels' environmental impacts, which leads to flawed conclusions as to their environmental balance.

In addition, the critical analysis of ways to make agrofuels more 'sustainable' led to a questioning of current agricultural practices but also to a questioning of the use of land and of the evolution of transport energy demand.

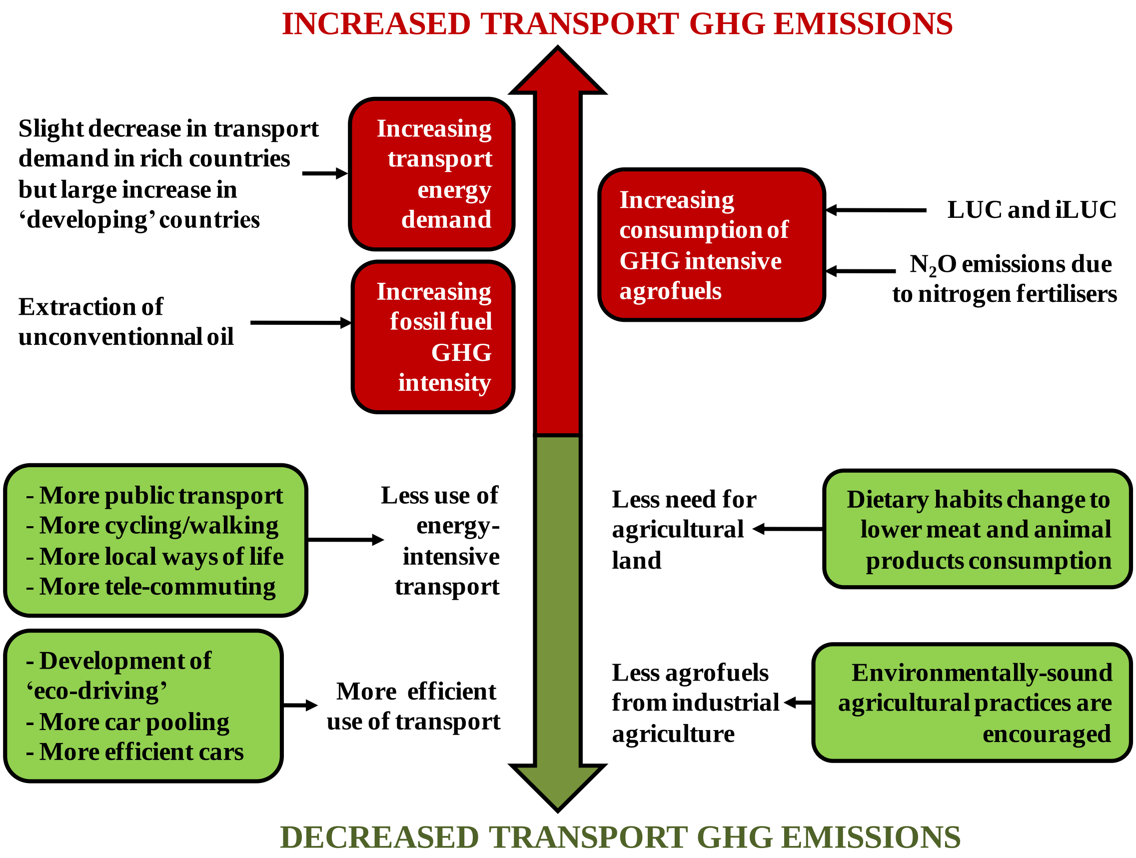
Indeed, one can wonder whether the current model of intensive farming relying on a heavy use of agrochemicals makes any sense environmentally speaking and *a posteriori* whether such a model can produce agrofuels that have a true environmental benefit.

As for the land use question, it was shown that livestock requires a considerable amount of land today. If one does not expect all from hypothetical technology fixes, then it seems that changing dietary habits by decreasing the consumption of animal products at the global scale would leave more space for agrofuel production (and reduce risks of iLUC associated with agrofuels) as well as bring significant environmental benefits and human health benefits.

Finally, considering today's rapid increase in transport energy demand, it appears that the - though very rapid - development of agrofuels cannot even compensate for the increase in transport energy demand. Thus, if transport GHG emissions are to be reduced, there is a need to rapidly decrease transport energy demand. This entails profound changes in the way our society is organised, by developing alternative ways of transport such as cycling, carpooling and a radical increase in the use of public transport. Transport needs could also be reduced for example by favouring more local lifestyles including telecommuting.

The following figure shows some of the main issues related to transport increasing GHG emissions (circled in red) and some associated demand-based mitigation options (circled in green):

Figure 58: Demand-based mitigation options to increasing transport GHG emissions



Source: Personal figure

If the points mentioned above are not rapidly taken into account in transport policies and agrofuel certification schemes, then agrofuels might look like a red herring in that they will be a distraction from the real environmental challenges that humanity is facing.

The next chapter will make a comparison of the actual contexts of agrofuels in France and in the United Kingdom, two countries that have radically different approaches.

Chapter 5:
Why such differences between French and British agrofuel policies?

"The best thing I know between France and England is the sea."

Douglas William Jerrold (1803-1857), English dramatist and writer

Introduction

Following the 2003/30/EC Directive, Member States of the European Union are recommended to increase the share of transport agrofuels in their road transport energy mix.

France and the UK have chosen two diametrically opposed policies. Whereas the French authorities massively increased agrofuel blending targets and even aimed at reaching 7% agrofuels blending by energy content by the end of 2010, the British authorities decided to reduce their targets of agrofuel blending to only 3.25% by volume for 2009/2010 (far below the EU recommended incorporation of 5.75% by energy content).

Such decisions of increase and decrease in agrofuel blending targets are linked to very different perceptions of agrofuels in France and in the UK. Whereas the French policy aggressively promotes agrofuels partly based upon controversial studies suggesting that agrofuels consumed in France lead to significant GHG emission reductions, the UK policy is much more cautious and also seems to rely on much more transparent studies (even though some shortcomings were identified for instance for the choice of agrofuels' GHG emissions default values). Moreover, the UK developed its own agrofuel certification scheme as well as methodologies for the calculation of agrofuels' GHG emissions at an early stage of its agrofuel policy development.

This fifth chapter aims at testing the following hypothesis: "the French and British agrofuel policies are very different but they are both based on objective science".

In the first instance, the evolution of agrofuel blending targets between the UK and France will be compared. Mistakes and anomalies in the French reports to the European Commission (EC) will be identified and the actual agrofuel share by energy content in France will be calculated and compared with the official French figures. Then the study will focus on the British view of agrofuels' environmental implications and the way agrofuels' GHG emissions are presented.

Finally, the agrofuel context in France will be critically analysed and potential reasons for differences between the French and British agrofuel policies will be presented.

Chapter objectives:

- Compare the evolution of the French and British targets of agrofuel blending with the European targets;
- Point out the anomalies found in the French reports to the European Commission on the implementation of Directive 2003/30/EC and determine actual agrofuel blending in France;
- Compare the evolution of agrofuels' consumption in France and the UK;
- Compare the evolution of road transport energy demand between France and the UK as well as with the European road transport energy demand;
- Analyse the differences in the perception of agrofuels' environmental balance between France and the UK;
- Point out anomalies in the British RTFO reports and analyse problems linked to the possibility to report 'unknown' for previous land use;
- Point out anomalies in the French studies on agrofuels' environmental impacts;
- Find explanations on why the targets changed in such different ways in France and in the UK.

5.1 Agrofuels' blending targets and consumption in France and in the UK

5.1.1 Two countries with very different agrofuel blending targets

Since the release in 2003 of the 'Agrofuel Directive' 2003/30/EC, all Member-States (MS) of the European Union are asked to "ensure that a minimum proportion of [agro]fuels and other renewable fuels is placed on their markets" (European Commission, 2003). The European Commission asks that MS set national indicative targets for agrofuel blending and suggests reference values for these targets (not compulsory):

- 2% agrofuels by energy content by 31st December 2005;
- 5.75% agrofuels by energy content by 31st December 2010.

The European Commission 2003/30/EC Directive also asks that MS report before 1st July each year on "the total sales of transport fuels and the share of [agro]fuels, pure or blended, and other renewable fuels placed on the market for the preceding year" and also indicate the level of their national indicative targets for the first phase in their first report (that of 1st July 2005) and their national indicative targets for the second phase in the report covering the year 2006 (European Commission, 2003).

All Member-States reports to the European Commission on the implementation of Directive 2003/30/EC can be found on the following webpage of the European Commission: http://ec.europa.eu/energy/renewables/biofuels/ms_reports_dir_2003_30_en.htm (EC Europa, 2010).

N.B.: It was chosen to keep the word 'agrofuel' for EU policy because even though the European Commission also promotes (at least on paper) other types of biofuels such as woodfuels, the majority of biofuels sold in Europe are by far 'agrofuels' (cf. chapter 2 for terminology).

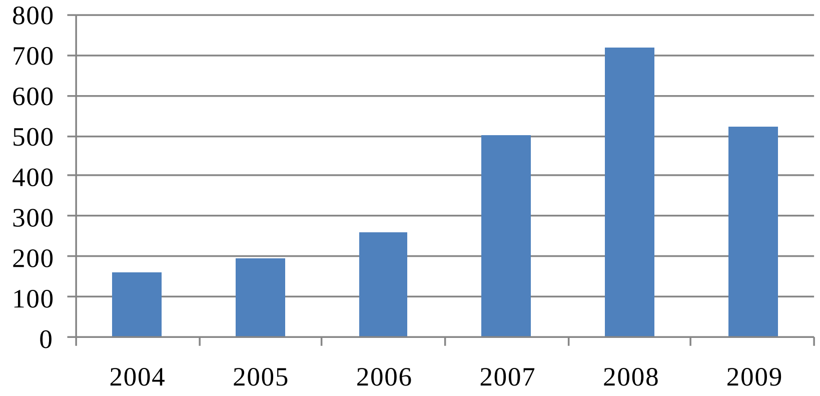
The United Kingdom and France have had two very different ways of promoting agrofuels, resulting in very different agrofuel blending targets.

The French Government indeed started to support agrodiesel (mainly rape methylester) and agroethanol (mainly from sugar beet and wheat) from feedstocks grown on set-aside land in 1992 through a partial tax rebate for production units that had governmental agreements (gained after bids). This scheme that was firstly possible thanks to a derogation from the European Commission (Hénard & Audran, 2003) then continued thanks to the issue of the Directive 2003/93/EC of the Council of the European Union that restructured the taxation of energy products at the end of the year 2003 (Council of the European Union, 2003).

Within the French scheme, agrofuels produced in production units under governmental agreements benefit from a reduction in excise duty the amount of which depends upon the type of agrofuel, and on the year. Thus, due to the rapid increase in the volume of agrofuels produced under governmental agreements, the French Government decreased the tax rebate per unit of volume of agrofuel (from 33€/hl in 2004 to 11€/hl in 2010 for agrodiesel for instance) for the total cost of the agrofuel tax rebate not to skyrocket.

The following graph shows the evolution of tax exemption for agrofuels in France from 2004 to 2010:

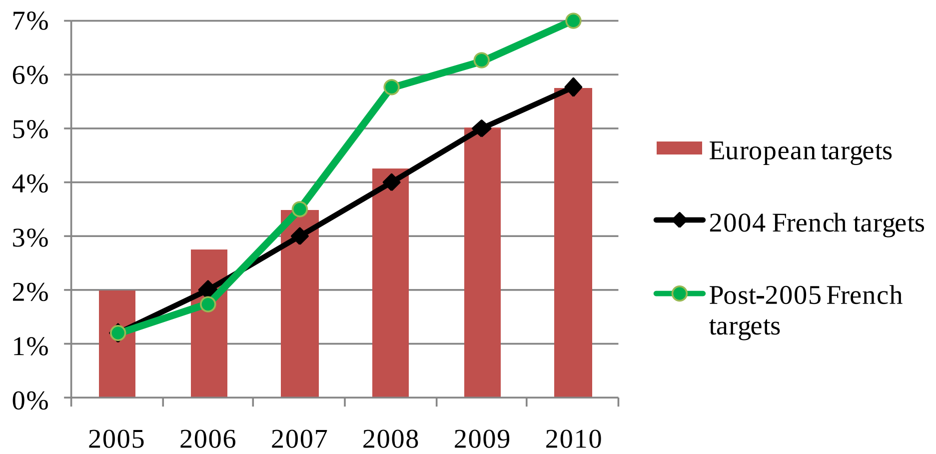
Figure 59: Evolution of the cost of the agrofuel tax rebate in France (in million euros)



Source: Personal graph made with data from the French reports to the European Commission on the implementation of Directive 2003/30/EC (EC Europa, 2010)

Despite the recent decrease in tax exemption for agrofuels in France, the French Government has had a very favourable policy towards agrofuels since 2005. Indeed, in the 2004 report, the agrofuel blending targets for 2010 of the French Government were the same as those of the 2003/30/EC Directive (5.75%). However, Dominique de Villepin (French Prime Minister at the time) announced on 13th September 2005 the intention of the French Government to "accelerate the development of [agro]fuels" together with supports to the French agriculture sector (Premier Ministre, 2005). The target of agrofuel blending was no longer 5.75% for 2010 but for 2008, 7% for 2010 and 10% for 2015. French targets thus exceeded European recommended targets for 2010 as early as from 2008. The following figure shows the evolution and the change of blending targets in France compared with those of the European Commission:

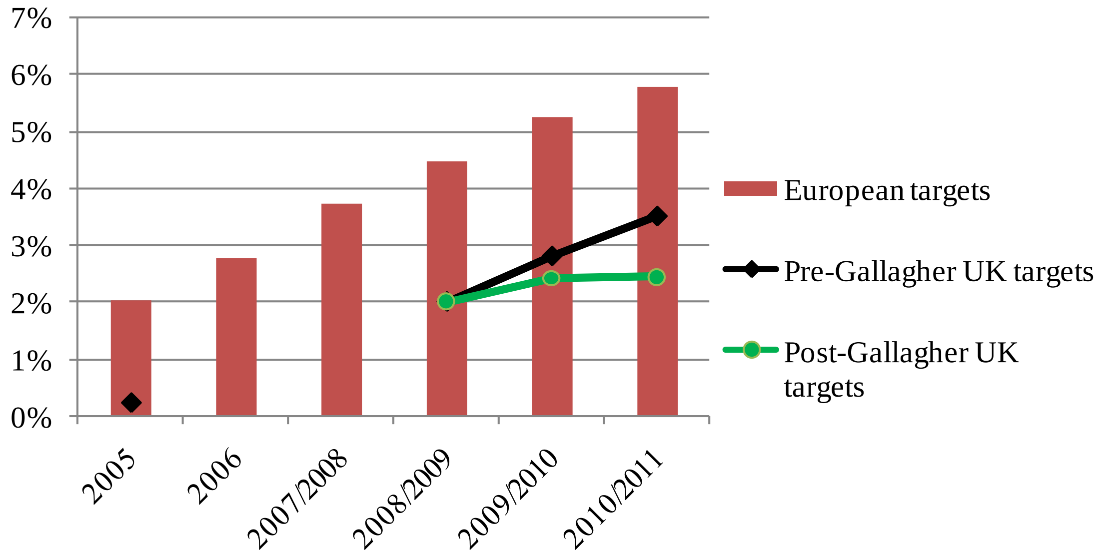
Figure 60: Evolution of agrofuel blending targets (by energy content) in France compared with European targets



Source: Personal graph made with figures from the French reports to the European Commission on the implementation of Directive 2003/30/EC and with intermediate European agrofuel blending targets calculated with a linear regression with the 2005 and 2010 reference values of the 2003/30/EC Directive.

The UK has also supported agrofuels with fuel duty incentives for several years (since July 2002 for biodiesel and since January 2005 for agroethanol). However, the UK Government had no concrete target for agrofuel blending before obligations (lower than the European targets) were set out in the 2006 Budget. Besides, the UK Government decided on April 15th 2009 to reduce the original 5% (by volume) blending target for 2010 to 3.5% following the release in July 2008 of the 'Gallagher review' (cf. next section) that recommended a reduction of the UK agrofuel blending targets "until adequate controls to address displacement effects are implemented and are demonstrated to be effective" (RFA, 2008b). The following figure shows the evolution of agrofuel blending targets in the UK compared with the recommended targets of the 2003/30/EC Directive:

Figure 61: Evolution of agrofuel blending targets (by energy content) in the UK compared with European targets



Source: Personal graph made with figures in energy content adapted from figures by volume content from the British reports to the European Commission on the implementation of Directive 2003/30/EC and with intermediate European agrofuel blending targets calculated with a linear regression with the 2005 and 2010 reference values of the 2003/30/EC Directive and weighted in order to correspond to RTFO years (15th April of year N to 14th April to year N+1).

Thus, the most recent British agrofuel blending target for 2010 was less than half that of the European Commission and barely more than one third of the French agrofuel blending target (in energy content).

5.1.2 Evolution of agrofuel consumption in the UK and in France

The evolution of agrofuel consumption (as presented in the French and British reports to the European Commission - one report every year from 2004 to 2010, thus 7 reports per country) followed radically different trends in France and in the UK.

It was thought interesting to calculate the consumptions and blending of agrofuels in France and in the UK and compare the results obtained with those found in the reports. It was also thought interesting to compare the presentation styles of the reports between the two countries because these differences in styles are evocative of different approaches to the promotion of agrofuels.

5.1.2.1 UK reports are transparent on the share of agrofuels in total road fuels

In the British reports, the data for agrofuel consumption and fossil fuel consumption have been expressed in volume by month since the 2006 report. Moreover, all reports since that of 2006 have mentioned a weblink that presents monthly sales by volume for all road transport fuels[33] starting from February 2007.

Besides, it is specified in the reports that fossil fuel consumption data include agrofuel consumption. It is thus easy to check figures of agrofuels' blending by volume, which happen to be right and precise. Moreover, the energy densities of agrofuels (per unit of volume) have been mentioned since the 2006 report. Agrodiesel has been said to have 92% of diesel energy content by volume since the 2006 report while agroethanol has been said to have 68% of petrol energy content by volume in the 2006, 2007 and 2008 reports but 66% in the 2009 and 2010 reports in order to comply with the conversion factors given in the Renewable Energy Directive.

Apart from figures for fuel LHVs that are missing (these data are available in reports from the Department for Transport and then from the RFA though (DfT, 2007; RFA, 2009b; 2010c)), all data necessary is available in each report in order to calculate very simply agrofuel blending by energy content which happen to match the official British figures (cf. section 5.1.2.3).

In short, the British reports to the EC are very clear and transparent in regard to agrofuel sales and their blending (especially by volume but calculations can easily be done for energy blending) in total transport fuels.

[33] Cf. https://www.uktradeinfo.com/index.cfm?task=bulloil

5.1.2.2 French reports to the European Commission contain numerous anomalies

On the opposite side, data in the French reports are all on a yearly basis and expressed in units that do not enable easy comparisons and calculations. The data for agrofuel consumptions are expressed in mass (but no conversion factor is provided in order to convert these data into volume or into energy units) while the data for fossil fuel consumption are expressed in volume or in mass every other year. It should be mentioned that the data on fossil fuel consumption for 2008 is extremely imprecise, and is altogether absent in the report on year 2009. Moreover it is never mentioned whether data for fossil fuel consumption includes agrofuels or not.

Elise Levaillant from the French Ministry of sustainable development eventually told me by email that 'fossil fuel' consumption (i.e. 'diesel' consumption and 'petrol' consumption) data included agrofuels.

However, 'diesel' consumption data published by UFIP (French Union of Petroleum Industries) (UFIP, 2010) – which also include agrodiesel consumption – are very different to those reported by the French authorities to the EC for 2007. As the UFIP data was thought more reliable for 2007, it was used in the blending calculations (cf. section 5.1.2.3).

After some research on the website of the French ministry of sustainable development, a table with the lower heating values (LHV) by mass and by volume as well as densities of the different road transport fuels was found (cf. following table). These data could eventually be used to calculate the actual amounts of fossil fuels consumed (from the given data of 'fossil fuels + agrofuels') as well as agrofuel blending by energy content.

Table 25: Mass LHV, Volume LHV and density of fuels chosen by the French authorities

Fuel	Mass LHV (kJ/kg)	Volume LHV (kJ/l)	Density (kg/l)
Petrol	42,900	32,389	0.755
Diesel	42,800	35,952	0.84
Ethanol	26,805	21,283	0.794
ETBE	35,880	26,910	0.75
Agrodiesel	37,400	33,024	0.883

Source: (Ministère de l'Ecologie, 2006)

However, it was observed that **some data were not consistent from one annual report to another**.

Indeed, the data on agrodiesel consumption of 2006, 2007 and 2008 are reported as different amounts in the 2008 and 2009 reports compared to the 2010 report. Actually, they are always lower in the 2010 report (cf. following table):

Table 26: Differences in the reporting of agrodiesel consumption (in tonnes)

Agrodiesel	2010 report	2009 and 2008 reports
2006	567 000	631 000
2007	1 146 000	1 300 000
2008	2 085 000	2 100 000

Source: French reports to the European Commission of years 2009 and 2010

Similarly, the data for annual consumption of agroethanol for direct blending and for agroethanol in ETBE for years 2006 and 2007 as reported in the 2007 to 2009 reports are very distinct (cf. following table):

Table 27: Anomalies in the French reports regarding the consumption in tonnes of agroethanol for direct blending and agroethanol in agro-ETBE

Agro-ETBE	2009 report	2008 report	2007 report
2006	146 000	217 000	220 000
2007	189 000	382 000	

Agroethanol	2009 report	2008 report	2007 report
2006	94 000	14 000	14 000
2007	232 000	44 000	

Agro-ETBE + Ethanol	2009 report	2008 report	2007 report
2006	240 000	231 000	234 000
2007	421 000	426 000	

Source: French reports to the European Commission of year 2007, 2008 and 2009 and personal calculation

However, it was calculated that the sum of the data of 'agroethanol for direct incorporation' and 'agroethanol in ETBE' gave approximately similar results for the 2007, 2008 and 2009 reports, which may show that a problem may reside in the separate figures rather than in the overall amount of agroethanol (that is agro-ETBE + agroethanol for direct blending).

It should be noted that **none of the above anomalies detected in the French agrofuel reports to the EC were officially mentioned by the French authorities to the EC at any point**, which raises the question of the reliability and transparency of the French data as well as the willingness of the French authorities to report on actual quantities of agrofuels consumed.

Finally, it is interesting to note that when dates of the time of expedition of the reports to the EC are indicated, those of French reports indicate some delay whereas the dates seen on several British reports indicate that they were sent on time, which can also be a piece of evidence showing some kind of bad will from the French authorities to report data on agrofuels sold in France according to the requirements of the European Commission.

5.1.2.3 Evolution of agrofuel consumption in the UK and in France

Since agroethanol and agrodiesel have different mass and volume LHVs, energy units must be used for a comparison to be meaningful. Therefore fuel consumption has been expressed as suitable energy units.

For the UK, volume LHV default values available in the RFA and DfT reports were used (these default values are the same in all the reports) and converted into toe/m^3 in order to be able to express agrofuel and fossil fuel consumptions in toe. For this, the conversion factor given by the IEA was used: 1 toe = 0.041868 TJ = 41,868 GJ [34].

Table 28: Volume LHVs selected by the UK for road transport fuels (in toe/m^3)

Fuel	Volume LHV (toe/m^3)
Petrol	0.774
Diesel	0.859
Ethanol	0.508
ETBE	0.643
Agrodiesel	0.789

Source: Personal calculations with data from RFA (2009a)

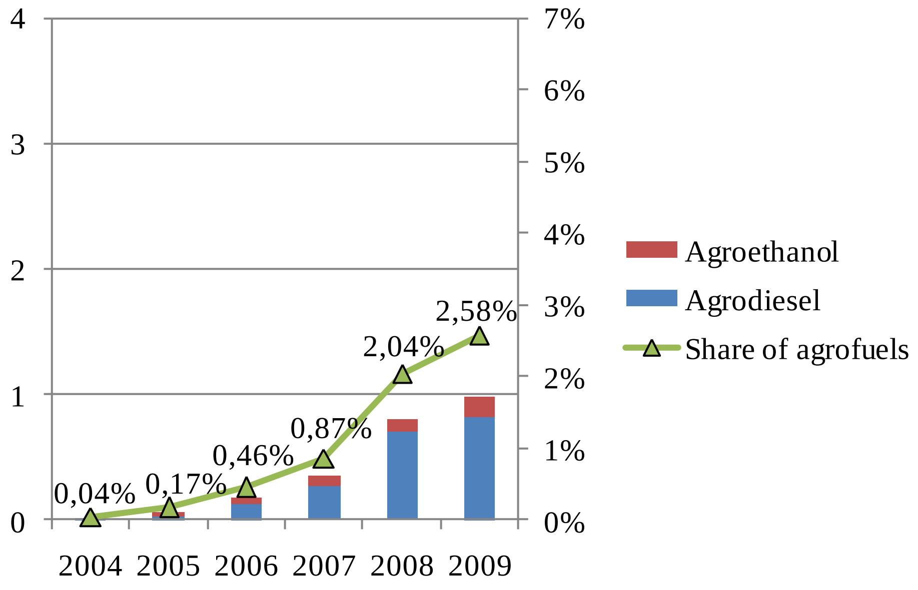
N.B.: With the above values, one can check that agrodiesel has about 92% of the diesel energy content by volume and that agroethanol has about 66% of the petrol energy content by volume as mentioned in the 2009 and 2010 UK reports.

When using the above LHVs, blending of agrofuels by energy content were calculated to be very close to the official blending mentioned by the UK reports.

The following figure shows the evolution of UK agrofuel consumption in energy content as well as the calculated agrofuel energy share per year (which is slightly different to the official data):

[34] Cf. http://stats.oecd.org/glossary/detail.asp?ID=4109

Figure 62: UK agrofuel consumption (in Mtoe) and blending of agrofuel by energy content

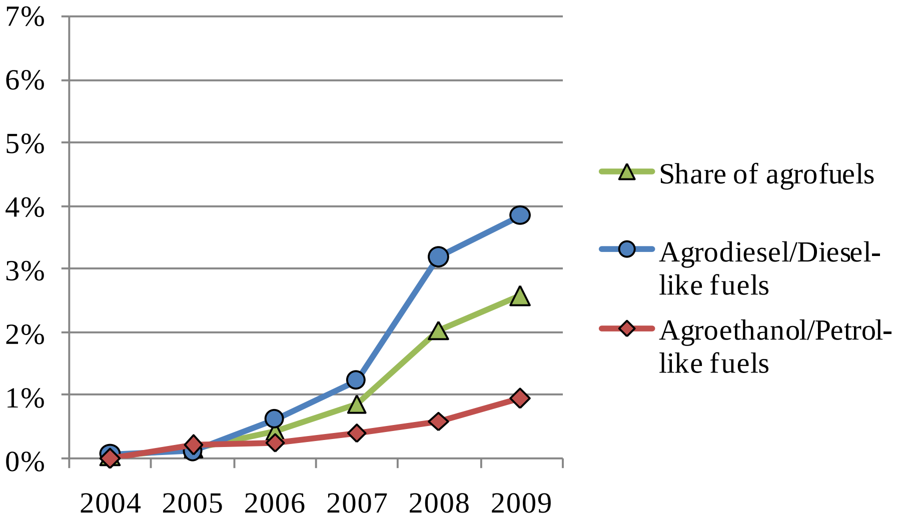


Source: Personal graph made after calculations presented above

Agrofuels' blending by energy content is about 2.6% of total transport fuels in the UK in 2009 despite a rapid increase in agrofuel consumption.

Moreover, whereas agrodiesel blending increased very rapidly, the share of agroethanol had a more modest increase (cf. following figure):

Figure 63: Evolution of agrofuel blending by energy content in the UK



Source: Personal graph made after calculations in energy content from the British reports to the EC

As for France, the task was much more arduous in part because of all the problems adverted to in 5.1.2.2 as well as other issues which had not been anticipated.

For instance, agro-ETBE is consumed in France. According to the EC 2003/30/EC Directive, **agro-ETBE is made of 47% of ethanol by volume**. Thus the figures of ETBE and ethanol densities from table 25 were used to calculate that **1 tonne of ETBE approximately 'contains' 0.4976 t of ethanol** (1 t of ETBE has a volume of 1 / 0.75 = 1.33 m^3 , which contains 1.33 x 0.47 = 0.627 m^3 of ethanol, which thus weighs 0.627 / 0.794 = 0.4976 t). This conversion factor could then be used to convert data of 'mass of ethanol in agro-ETBE' consumption into mass of agro-ETBE consumed.

With the density values of table 25, the quantities of agrofuels (expressed in mass) could be expressed in volumes for the years for which fossil fuel consumptions were expressed in volumes.

Indeed, since 'fossil fuel consumption data' (meaning 'consumption of agrofuels + fossil fuels') are sometimes expressed in volume and sometimes in mass, 'diesel-only' consumption and 'petrol-only' consumption needed to be calculated, either in mass or in volume. Then it was possible to convert all fuels' consumption expressed in mass or in volume into energy consumption. Similarly to the methodology used for the UK, the default volume and mass LHVs from table 25 were converted into toe/t and toe/m^3 respectively thanks to the IEA value for 1 toe in GJ used for table 28 (cf. following table):

Table 29: Volume and mass LHVs selected by France for road transport fuels expressed (in toe/t and toe/m^3)

Fuel	Mass LHV (toe/t)	Volume LHV (toe/m^3)
Petrol	1.025	0.774
Diesel	1.022	0.859
Ethanol	0.640	0.508
ETBE	0.857	0.643
Agrodiesel	0.893	0.789

Source: Personal calculations with data from Ministère de l'Ecologie (2006)

N.B.: Volume LHV default values are exactly the same in France and in the UK.

Then, agrofuel blending (ethanol share in total petrol-like fuels and agrodiesel share in total diesel-like fuels) could be calculated.

Since data for agrofuel consumption for a specific year sometimes differ from one report to another, different data were tried for the calculation of agrofuel blending.

It was found that the calculated shares of agrodiesel in total diesel-like fuels approximately corresponded to the official shares for all years if data of consumption of agrodiesel in 2006 and 2007 were those presented in the 2008 and 2009 reports (or in other words the values presented in the 2010 report for agrodiesel consumption in 2006 and 2007 did not lead to calculations that matched the official agrodiesel blending in diesel-like fuels).

As for agroethanol, there is no ambiguity with the 2004 and 2005 data because there is only one figure for each year. However, it was found that the calculated share of agroethanol in 'petrol-like fuels' only matched French official blending data when in the calculation of the consumption of ethanol in agro-ETBE **the agroethanol share in agro-ETBE was given the volume LHV of agro-ETBE**.

Knowing that agro-ETBE is considered to contain 37% of renewable energy according to the 2009/28/EC Directive, the following calculations were done with densities from table 25 and with energy densities from the 2009/28/EC Directive (European Commission, 2009a) in order to check what LHV should be used for agroethanol in agro-ETBE:

- By mass: 1 kg of agro-ETBE has an energy of 1 x 36 = 36 MJ and measures 1 / 0.75 = 1.33 L.

  Since agro-ETBE contains 47% of ethanol by volume, 1 kg of agro-ETBE contains 1.33 x 0.47 = 0.627 L of ethanol, which contain 0.627 / 21= 13.16 MJ, that is 13.16 / 36 = 36.6% of the energy in 1 kg of agro-ETBE.

- By volume: 1 L of agro-ETBE has an energy of 27 MJ and contains 1 x 0.47 = 0.47 L of ethanol, which have an energy of 0.47 x 21 = 9.87 MJ, that is 9.87 / 27 = 36.6% of the energy in 1 L of agro- ETBE.

Both calculations lead to an energy content of about 37% of ethanol per mass or volume unit of agro-ETBE, which is the one given in the 2009/28/EC Directive. Thus, **the energy content of the ethanol part of agro-ETBE should be calculated by using the ethanol LHV**.

Within the French reports, according to our calculations, the mass of agroethanol contained in agro-ETBE is attributed the energy density of agro-ETBE. Therefore, **according to the figures used by the French authorities, the energy content of agroethanol in agro-ETBE is not 37% as said by the 2009/28/EC Directive but 49.76%,** which is 34% higher (the energy density or LHV of agro-ETBE is indeed 34% higher than that of agroethanol).

This mistake in the choice of the LHV for the agroethanol part in agro-ETBE in the French reports leads to an overestimation of the total agroethanol blend in petrol-like fuels since agroethanol for direct incorporation and agroethanol in agro-ETBE are summed for the calculations of the energy blending of total agroethanol in petrol-like fuels.

However, according to Karine Brûlé from the French Ministry of Agriculture (during a telephone interview), this choice of ETBE LHV for ethanol contained in agro-ETBE was actually not a mistake but was a strict application of the French official methodology choices which happened to be wrong. According to her, the next reports will use the European figure of 37% from the 2009/28/EC Directive cited above. But it seems improbable that French authorities will recognise the mistake that was made in the former reports!

Our calculations also closely matched official figures of agroethanol blend in petrol-like fuels for 2006 when ethanol in agro-ETBE was once again attributed agro-ETBE mass LHV and when data found in the 2009 and 2010 reports were used.

But for 2007, with the same trick of ETBE LHV value for the ethanol part of ETBE and by using data from the 2008 report, it was not possible to find the same value for agroethanol blend. However, the calculated agrofuel blend in total transport fuels was found to match the official figure. Therefore, it is assumed that there is probably a mistake in the writing of the agroethanol share for year 2007 (official figure is 3.35% while the calculated figure – with the LHV mistake and the use of data from the 2008 report – is 3.50 %).

Finally, there was no solution found in order to make calculated targets for agroethanol blend for 2008 coincide with French official targets, which might be the sign that either the data are flawed, or that there are additional mistakes in the calculations made by the French authorities that were not identified.

Since data of fossil fuel consumption for 2009 were not available in the 2010 report, I asked Elise Levaillant from the French Ministry of Sustainable Development for data and received from her the data that were used for the 2010 report by French Customs authorities. Her administration noticed that in the calculation made by the Customs (and used as official data of agrofuel blending by energy content in the 2010 report), 'total petrol' and 'total diesel' were wrongly attributed LHV of petrol and diesel whereas they should have been disaggregated taking into account LHVs of agro-ETBE, ethanol and agrodiesel. I could also notice that the LHV used for ethanol in agro-ETBE was wrongly attributed the LHV of agro-ETBE.

Finally, data of fuel consumption in this spreadsheet were given in volume (litres) and were not consistent with consumption data expressed in mass found in the 2010 report.

We used volume data of all fuels found in this spreadsheet to make conversions in energy content and calculate agrofuel blending by energy share for 2009. All data of fuel consumption in France that were used for the calculations of consumptions in energy terms and agrofuel blending by energy content can be found in tables 49 and 50 of Appendix C.

The following tables (30 to 32) show the discrepancies between the calculated shares of agrofuels (calculations with agroethanol LHV attributed to agroethanol in agro-ETBE and with the use of data that seem to have been used by the French authorities) and the official shares found in the French reports:

Table 30: Discrepancies between the calculated shares and the official figures of agrodiesel blending in total diesel fuels in France

	Calculated % of agrodiesel in diesel	Official % of agrodiesel in diesel
2004	0.93%	0.93%
2005	1.04%	1.04%
2006	1.77%	1.77%
2007	3.50%	3.63%
2008	5.78%	5.75%
2009	6.30%	6.27%

Most discrepancies between calculated shares of agrodiesel in diesel-like fuels and official data were found to be negligible when appropriate data of agrodiesel consumption were used and when the data of 'diesel' consumption was understood as 'diesel + agrodiesel' consumption. The major discrepancy is for the agrodiesel blending in 2007 and is due to the fact that in our calculations, the UFIP data of 'diesel+agrodiesel' consumption was used.

Table 31: Discrepancies between the calculated shares and the official figures of agroethanol blending in total petrol-like fuels in France

	Calculated % of ethanol in petrol	Official % of ethanol in petrol
2004	0.43%	0.58%
2005	0.67%	0.89%
2006	1.47%	1.75%
2007	2.69%	3.35%
2008	4.16%	5.55%
2009	4.65%	5.24%

On the other hand, **very large discrepancies** were observed between calculated shares of agroethanol in total petrol-like fuels when data which seem to be have been used with the LHV mistake were used and when the LHV mistake was corrected. The calculated shares fall short of those officially presented in the French reports.

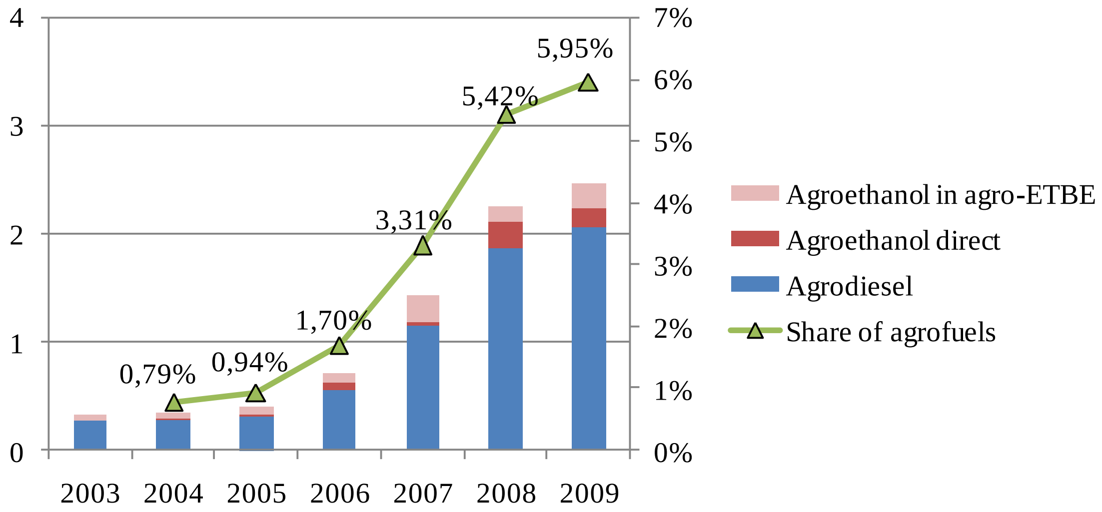
Table 32: Discrepancies between the calculated shares and the official figures of total agrofuel blending in total fuels in France

	Calculated % of agrofuels in total fuels	Official % of agrofuels in total fuels
2004	0.79%	0.83%
2005	0.94%	1%
2006	1.70%	1.77%
2007	3.31%	3.63%
2008	5.42%	5.71%
2009	5.95%	6.04%

Finally, the mistakes found in the methodologies used for the calculations of agroethanol shares by the French authorities had a moderate impact on the differences observed between the calculated shares of all agrofuels in total transport fuels compared with the official data because the volume ratio of petrol-like/diesel-like fuels is nearly 1/4 in France.

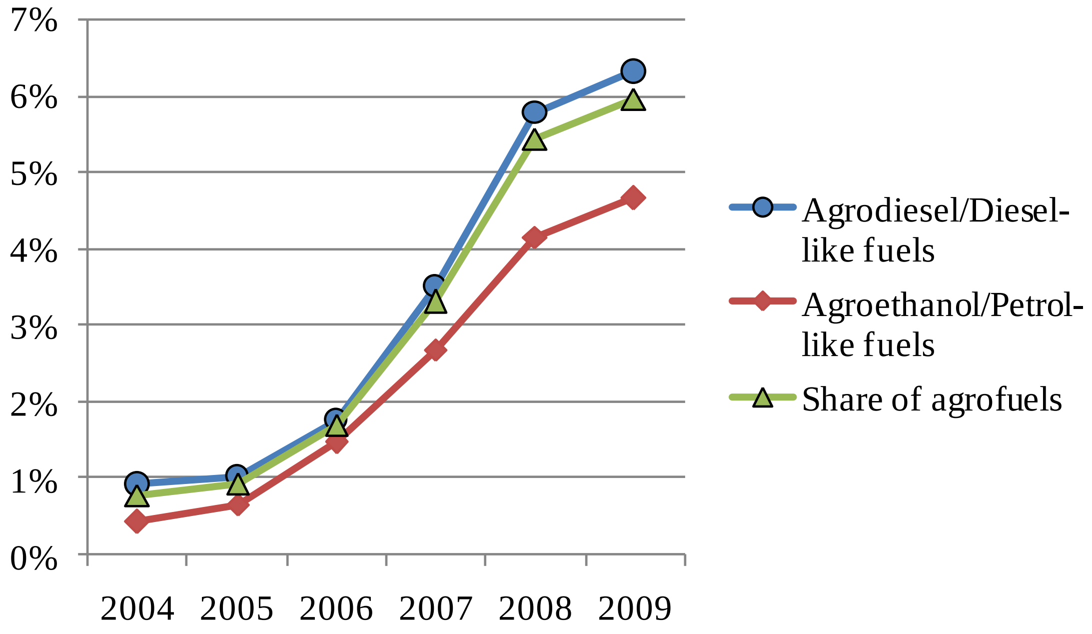
The following graph shows the evolution of agrofuel consumption by energy content in France as well as the evolution of the share of agrofuels (by energy content) in total transport fuels. The increases in agrofuels' consumption and agrofuels' share have been phenomenal in France between 2005 and 2008. However, the consumption of agrofuels has been practically stable between 2008 and 2009. It is interesting to note that the consumption of agroethanol in agro-ETBE largely decreased between 2007 and 2008 at the benefit of agroethanol for direct incorporation.

Figure 64: France calculated agrofuel consumption (in Mtoe) and blending of agrofuel by energy content



Unlike the UK, the blending of agrodiesel in total diesel and agroethanol in total petrol are not too different in France. However, agroethanol energy blend increased at a lower pace than agrodiesel between 2006 and 2008 (cf. following figure):

Figure 65: Evolution of calculated agrofuel blending by energy content in France



Source: Personal graph made with data obtained after calculation from the methodologies and data described above

5.1.3 Evolution of transport energy demand in the UK and in France

With all the data calculated above, it was then possible to have a more realistic grasp of the evolution of road transport energy profiles in France and in the UK, which are presented in the following figures:

Figure 66: Evolution of the UK road transport energy profile between 2004 and 2009 (in Mtoe)

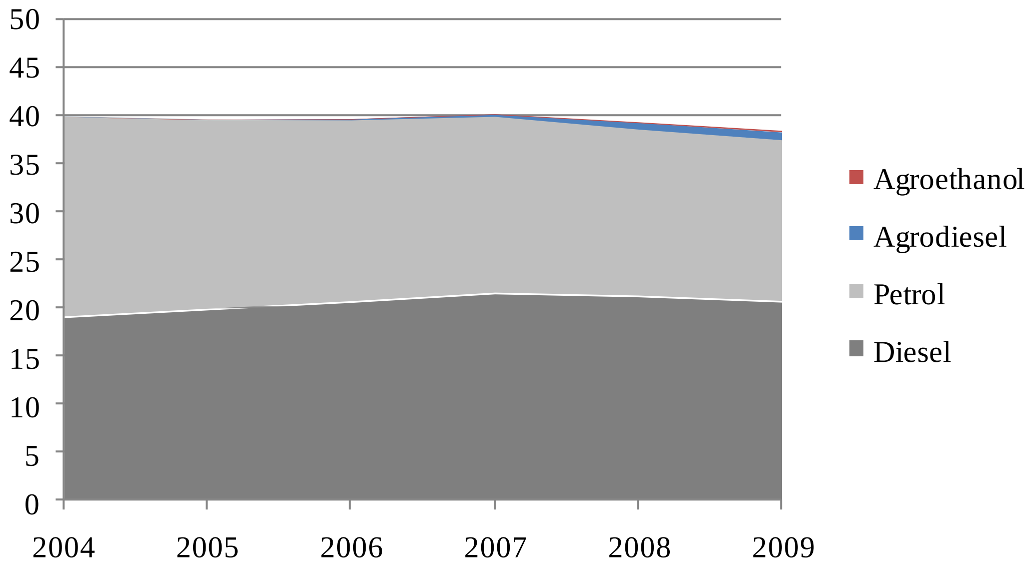
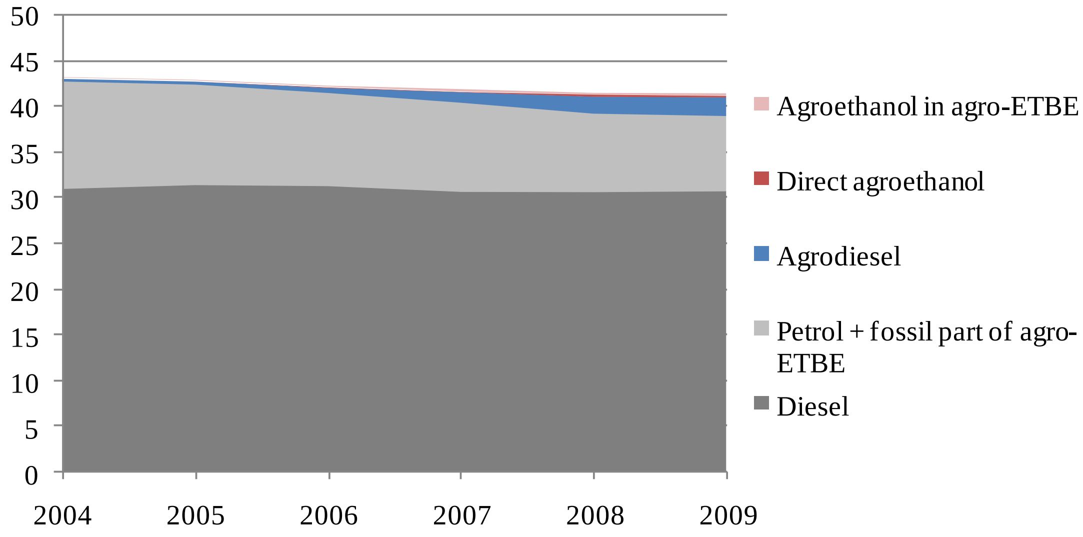
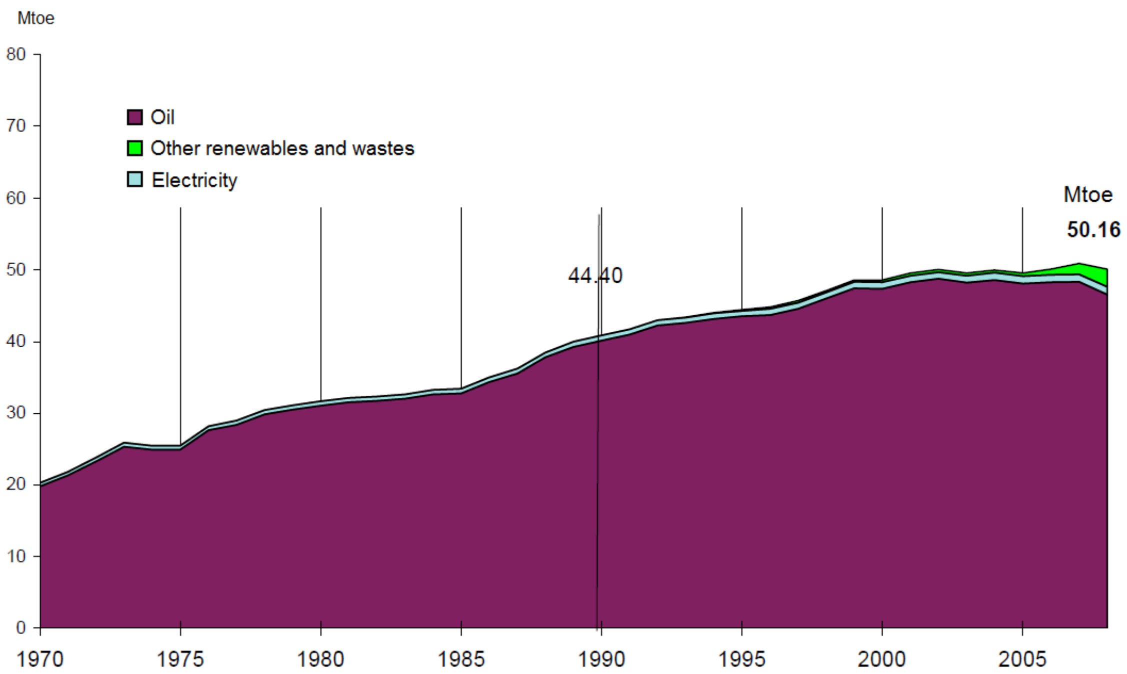


Figure 67: Evolution of the French road transport energy profile between 2004 and 2009 (in Mtoe)



Both countries show a slight decrease in their road transport energy demand. Thus, in these countries, at the national level, agrofuels are substitutes for fossil transport fuels. The increase in agrofuel consumption in France and to a lesser extent in the UK accelerates the decrease in fossil transport fuel consumption. However, according to the French statistics, despite the recent rapid increase in agrofuel blending and a record 1.5% decrease in transport energy consumption in 2008 (probably due to the spike in fuel prices) comparable to that of the first oil shock of 1974, total transport energy consumption in France is still 93% dependent on oil (cf. following figure):

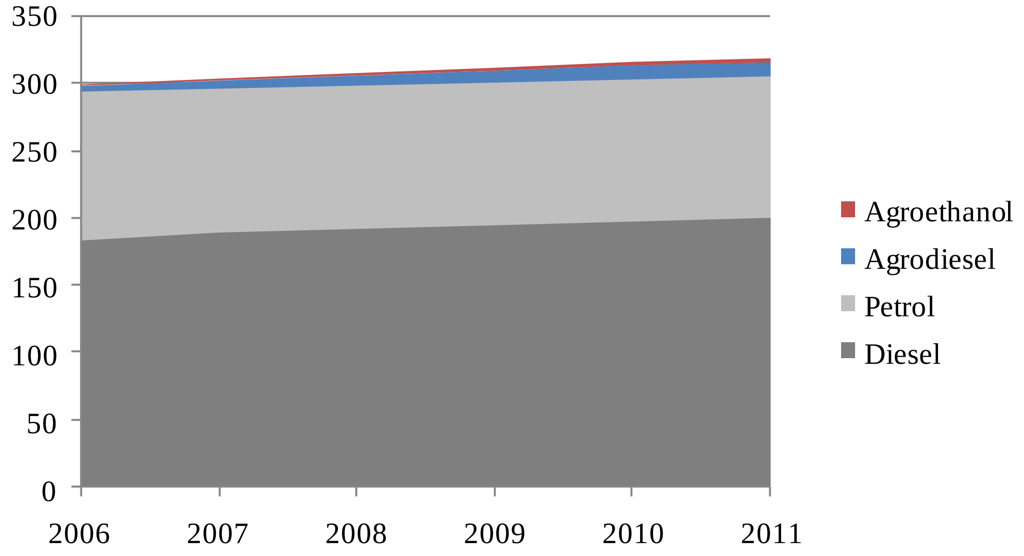
Figure 68: Evolution of the transport energy mix in France (in Mtoe)



Source: Adapted from Commissariat Général au Développement Durable (2009)

Moreover, it should not be forgotten that at the regional scale, road transport energy demand still increases (cf. following figure):

Figure 69: Evolution of the European road transport energy profile (in Mtoe) between 2006 and 2011 (projected figures for 2010 and 2011)



Source: Personal graph made with data gathered and presented in Flach (2010)

Thus, at the European scale, agrofuels do not substitute for fossil fuels. They add up to approximately stabilized fossil transport fuel consumption. This can be explained by the fact that some European countries are 'developing' and thus increasing their transport energy consumption per capita from low values. The limited decrease in transport energy demand in most 'developed' countries in Europe is thus not sufficient to compensate for the increase observed in 'developing' European countries.

Since agrofuels at best probably bring little GHG benefits (cf. chapter 4), for more equity in road transport GHG emissions to be achieved at the regional level (and to a bigger extent at the world level), if it is thought necessary to stabilize road transport GHG emissions, then most 'developed' countries such as France and the UK must LARGELY decrease (especially for a world with a better share of road transport GHG emissions per capita) their road transport energy demand.

5.2 The British agrofuel policy is cautious and partly transparent

5.2.1 The choice of an environmental certification

The British authorities have had a "measured approach to the promotion of [agro]fuels"(cf. 2004 British reports to the EC (EC Europa, 2010)) that is continuously found in the British reports to the EC. For instance, in the 2006 report, the UK "acknowledges the serious risk that biomass could be produced from highly unsustainable sources which could potentially undermine the central environmental policy objective".

Therefore, the UK authorities developed a 'Carbon and Sustainability' Assurance scheme for agrofuels that includes environmental and social principles (cf. following table):

Table 33: Environmental and social principles of the British RTFO

Environmental principles
1. Biomass production will not destroy or damage large above or below ground carbon stocks
2. Biomass production will not lead to the destruction or damage to high biodiversity areas
3. Biomass production does not lead to soil degradation
4. Biomass production does not lead to the contamination or depletion of water sources
5. Biomass production does not lead to air pollution
Social principles
6. Biomass production does not adversely affect workers rights and working relationships
7. Biomass production does not adversely affect existing land rights and community relations

Source: (DfT, 2007)

The UK is thus among the first countries that developed 'sustainability principles and criteria' for agrofuels (ECCM *et al.*, 2006; DfT, 2007). It then included these principles in its Renewable Transport Fuel Obligation (RTFO) that came into force on May 15th 2008. The Renewable Fuels Agency (RFA) - self-proclaimed 'independent' regulator in that it is a 'Non-Departmental Public Body' - was especially created in late 2007 in order to implement the RTFO.

During the first year of the RTFO, 73% of agrofuels consumed in the UK came from reported imported feedstocks, 19% were of 'unknown' origin (most of these were probably imported) while only 8% came from reported UK-grown feedstocks (RFA, 2010d). In this context, it seems understandable that the British authorities do not want to promote imported agrofuels that deliver poor environmental performances and have stressed the importance of agrofuel certification schemes since their first report to the EC after the adoption of the 2003/30/EC directive.

Thus, for its 'Sustainability Assurance Scheme', the UK chose to develop a 'meta-standard', that is to say a standard that builds "upon existing assurance schemes […] and works through a benchmarking (cross-compliance) framework which compares the requirement of the draft standard with the requirements of existing agri-environmental assurance schemes" (ECCM *et al.*, 2006).

In order to show the level of performance it expects from agrofuel suppliers, the British Government set non-mandatory targets for:

- percentage of feedstock meeting a Qualifying Standard;
- annual GHG saving of fuel supplied;
- data reporting of sustainability characteristics.

However, the following table shows that expected annual GHG emission savings from agrofuels were reduced between the first draft of the Department for Transport of 2007 and its 2008 'Requirements and Guidance', probably because the original aims were considered to be too optimistic.

Table 34: Change in annual supplier targets of agrofuel GHG emission reductions

Annual supplier target	2008-2009	2009-2010	2010-2011
Original indicative annual GHG savings of fuel supplied (2007)	40%	50%	60%
Subsequent indicative annual GHG savings of fuel supplied (from 2008)	40%	45%	50%

Source: (DfT, 2007; 2008)

These GHG emission reduction targets are linked to default values and to methodologies for the calculation of agrofuels' GHG intensities that will be expanded upon in the next section.

5.2.2 Agrofuel GHG emission reduction default values

The UK developed methodologies for the calculation of the GHG intensities of agrofuels depending on the agriculture feedstock, the country of origin, the energy process used for the agrofuel production, etc. (Bauen *et al.*, 2008).

Nota Bene: As was shown in the previous chapter, GHG LCAs used in the British reports are partial in that they do not include secondary and tertiary impacts and also ignore iLUC GHG emissions.

These methodologies were used to create tables with default values for GHG intensities depending on the feedstocks and their country of origin (DfT, 2007; 2008; RFA, 2009b; 2010c). These GHG intensity default values evolved along the reports (cf. following figure):

Table 35: Default GHG intensities of selected agrofuels in the UK reports (in gCO_2e/MJ)

	2007 DfT report	2008 DfT report	2009 RFA report	2010 RFA report
Agroethanol	78	61	115	115
SC ethanol	No default value	61	25	24
Agrodiesel	77	55	93	93
Soy agrodiesel	59	78	78	58
OSR agrodiesel	77	55	93	52

Source: (DfT, 2007; 2008; RFA, 2009b; 2010c)

One can notice that the 2010 RFA report (which is 'RED-ready' and thus uses default values found in the European Renewable Energy Directive) proposes very different choices of default values than other reports. Default values are much more conservative for agroethanol and agrodiesel from unspecified feedstock but more generous for specified feedstocks (at least in the case of sugar cane SC, soy and oilseed rape OSR) than in earlier reports.

It seems that default values of agrodiesel were chosen to be that of OSR agrodiesel between 2007 and 2009 probably because OSR agrodiesel is one of the most consumed agrofuels in the UK, though after soy agrodiesel.

It is interesting to note that the 2007 and 2009 reports cited above have more conservative values for agrodiesel from unreported feedstock than that of the 2008 report. Indeed, the 2007 and 2009 reports chose the worst default values for agrodiesel from non-reported feedstock, for soy agrodiesel (that from Brazil) and for OSR agrodiesel (those from the US or Canada).

As for agroethanol, the chosen default value was about half the worst default values in 2007 and 2008 (US maize ethanol in 2007 and sugar cane agroethanol from Pakistan in 2008) but eventually matched the worst default value in the 2009 report (sugar cane agroethanol from Pakistan).

Interestingly, there was no default value for sugar cane ethanol in the 2007 report. Fuel suppliers were asked to either determine the origin of the feedstock – if from Brazil, it was attributed a rather good default GHG intensity, if from somewhere else then calculations of the GHG intensity could be made using the methodology – or to use the default value of agroethanol from unspecified feedstock which was not very favourable. Interestingly, in 2008, the sugar cane default value was only half the worst sugar cane default value (Pakistan sugar cane agroethanol) and in the 2009 report, sugar cane default value was chosen to be the best default value (that of sugar cane ethanol from Brazil).

It should be noted that although fuel suppliers are encouraged to specify the type and country of origin of the feedstocks of the agrofuels they supply, they are allowed to report ‘unknown’ without any penalty.

The observations above show an important pitfall of this system: **when non-conservative default values are chosen for agrofuels with unspecified feedstock or country of origin, there is an incentive for agrofuel suppliers not to specify the origin or type of their feedstock in the case when their specified default values would be higher than the non-specified default values.**

Moreover, there has been much variation and inconsistency in the default values, which suggests that such default values are not only highly subjective but also very controversial.

5.2.3 Apparently transparent RTFO allows cheating

Since 15th April 2008, fuel suppliers are required to report on the type of feedstock of the agrofuels they supply, the origin of the feedstocks and whether their cultivation is done under standards that have been benchmarked against the RTFO meta-standard although ‘unknown’ can be reported for all these categories without any penalty. All these data are then aggregated each month in RTFO reports that are available on the following link: http://www.renewablefuelsagency.gov.uk/carbon-and-sustainability/rtfo-reports (accessed in November 2010).

Since the RTFO reports are done on a monthly basis, they do not allow a good view on the evolution of agrofuels’ consumption by feedstock.

Moreover, although the data of agrofuel consumption were given for each month for the first three RTFO reports (those of April-May, May-June and June-July 2008), data presented in the following RTFO reports are cumulative (aggregate) data of agrofuel consumption since the beginning of the ‘RTFO-year’ (15th April 2009 for reports of the first year of the RTFO and 15th April 2010 for reports of the second year of the RTFO). In order to be able to follow the declared monthly consumption of agrofuels it was decided to disaggregate all data from the 4th RTFO report, by simply subtracting the data of the report of month N-1 to the data of the report of month N.

The task was much more tedious than it may seem because from one monthly report to another, new types of agrofuels, agrofuel feedstocks and previous land-use appeared (or sometimes disappeared, which is inconsistent), but they had to be integrated into the spreadsheet.

The results of this compilation were presented in the form of tables of agrofuel monthly consumption separated into 4 semesters. These are tables 38 to 47 that can be found in Appendix A.

Numerous inconsistencies were detected in the data of the reports. For instance, the cumulative sales of specific agrofuels for month N were sometimes found to be lower than those of month N-1. Sometimes, this could be explained by the fact that mistakes were probably simply made in the reporting from the RFA staff, but perhaps this type of human error is not the only explanation.

The mistakes found that were thought to be without much consequence are the following:

- sometimes, positive and negative calculated figures of the consumption of a specific agrofuel do compensate because at some point, the original 'unknown' country of origin becomes known (for instance Malawi for molasses in October-November 2009);
- some feedstocks are attributed impossible previous land use such as sugar cane reported as 'by-product' or tallow reported as from 'unknown' previous land use or from 'cropland' before being eventually corrected with the previous land use, respectively 'cropland' and 'by-product';
- monthly calculated data of palm oil agrodiesel from the US for July-August 2008 and August-September 2008 offset each other. This is probably due to the fact that either this palm oil actually did not come from the US (and was thus reported in August-September 2008 as palm oil from another country than the US) or this agrodiesel was not made from palm oil, and was thus reported in August-September 2008 as agrodiesel but from another US feedstock (OSR, soy or tallow). This similar situation happens for soy from Belgium and from the UK in 2009-2010;
- large negative figures are sometimes found in 'unknown', which is probably due to the fact that the type of fuel, feedstock or previous land use is finally known and reported in the appropriate cell.

However, some anomalies in the RTFO reports have larger consequences than the small mistakes identified above. In several of the first RTFO reports, some data of agrofuels whose feedstocks come from land that was 'grassland in agricultural use' on 30th November 2005

partly to totally disappeared in the subsequent RTFO reports, probably (in some cases there is no doubt) at the benefit of 'unknown' previous land use.
Thus all OSR from Finland and France, palm from Indonesia and soy from Brazil reported as coming from land whose previous land use was 'grassland in agriculture use' disappeared. As to OSR from 'grassland in agriculture use' from Germany, only less than 1 million litres remained out of the 8.5 million litres originally declared. Most of them were probably reported as 'unknown' in the September-October 2008 report since the reported German OSR from 'unknown' previous land-use suddenly jumped from not more than 6.1 million litres of agrodiesel per month to more than 20 million litres in that report.

It is important to understand that reporting 'grassland' as the previous land use (that on 30th November 2005) of the land where the agrofuel feedstock is cultivated seriously increases agrofuel GHG intensity and even makes agrofuels more GHG-intensive than fossil fuels (cf. following figure):

Table 36: Calculated default GHG emission reductions depending on former land use

		Previous land use	
Feedstock	Country of origin	Cropland	Grassland
OSR	Finland	38%	-180%
OSR	France	47%	-50%
OSR	Germany	44%	-96%
Palm	Indonesia	46%	-101%
Soy	Brazil	10%	-781%

Source: Personal table made after calculations with data from RFA (2008a)

However, it was decided for RTFO reports that "where information [on previous land use] is not provided (i.e. 'unknown' is reported) the calculation does **not** require the use of a default value for land-use change impacts" (RFA, 2008a). Therefore, default values of agrofuels whose feedstocks are grown on land with 'unknown' previous land use are the same than those for which previous land use was cropland.

Considering the very large penalty attributed to agrofuels reported as coming from grassland and the leniency toward agrofuels from 'unknown' reported previous land use, there is no interest for fuel suppliers to report actual previous land use other than cropland. Therefore, the anomalies detected above are probably due to the fact that some fuel suppliers may have come back over their initial declaration ('grassland') and preferred to declare their agrofuels as from land with 'unknown' previous land use. Since this is also probably in the interest of the British authorities who may want to show they ensure that only 'good' agrofuels are sold in the UK, it is understandable that these anomalies occurred even though they look like a sign of dishonesty on both sides.

It is interesting to note that since the September-October 2008 RTFO report (6th monthly report), no agrofuel was reported with previous land use other than ‘cropland’, ‘by-product’ (for tallow, used cooking oil, molasses and MSW) or ‘unknown’. The exceptions to these reported types of previous land use were only detected before that report and were the feedstocks from former ‘grassland in agricultural use’ cited above. This might be the sign than since then, all agrofuels whose feedstock came from land that had underwent recent land-use change have been declared as from ‘unknown’ previous land use (there might have been other agrofuels with such feedstocks in the first reports too).

However, the ‘grassland in agricultural use’ to ‘unknown previous land use’ anomaly is probably only the visible part of the problematic previous land use of a more important amount of feedstocks processed into agrofuels sold under the RTFO, which cannot be detected because of a lack of data and also of some lack of transparency from the RFA.

According to tables 4 and 5 of the RTFO report number 24 (last report of the second year of the RTFO), 36% by volume of all agrodiesel sold under the RTFO came from feedstock with ‘unknown’ previous land use while this figure is 12% for agroethanol. However, according to table 1 of this same report, agrofuels sold under the RTFO in year 2009-2010 are said to provide 51% GHG emission savings compared with fossil fuels, against a target of 45% (46% GHG emission savings were said to be achieved in 2008-2009 against a target of 40%). Considering the very important anomalies mentioned earlier in the way agrofuels GHG default values are chosen, one can have doubts on the representativeness of such good figures of GHG emission reductions (Upham *et al.*, 2009).

In conclusion, it seems that the following pitfall, close to that identified in 5.2.2, has to some extent been exploited here: **since non-conservative default values are chosen for agrofuels with unspecified previous land use, there is an incentive for agrofuel suppliers not to specify the previous land use of the land where agrofuel feedstock was cultivated when their specified default values are higher than the non-specified default values.**

Thus, although the RTFO makes lots of data on agrofuel consumption available, it includes measures that can be seen as incentives for cheating, which radically contrasts with the apparent transparency of data on the volumes of each specific agrofuel sold (accurate to within a litre).

5.2.4 Perception of iLUC in the UK context

Soon after the release of his famous paper on iLUC GHG emissions from agrofuels in Science (Searchinger *et al.*, 2008), Timothy Searchinger came to Imperial College London to give a talk on iLUC on March 13th 2008. At the end of his conference, Sue McDougall, acting CEO of the Renewable Fuels Agency announced the launching by the RFA of a call for evidence on the 'indirect effects' of agrofuels ending on 11th April 2008 (RFA, 2008c).

About a month after the closing of the call for evidence, a one-day workshop called: "RFA Review into the Indirect Effects of Biofuels: Stakeholder review of evidence" took place in Birkbeck College on 22nd May 2008. However, it was surprising to see that during this workshop, most presentations did not even mention iLUC while the few that did usually presented Searchinger's paper as flawed and most agrofuels' iLUC as leading to lower GHG emissions than those calculated by Searchinger *et al.* for US maize ethanol. Numerous reports had been written in preparation of this one-day workshop (AEA Technology plc., 2008; Bates *et al.*, 2008; Croezen & Brouwer, 2008; Dehue & Hettinga, 2008; Dehue *et al.*, 2008; E4Tech, 2008c; a; b; Kampman *et al.*, 2008; Kindred *et al.*, 2008b; Mortimer *et al.*, 2008; Sylvester-Bradley, 2008; Wiggins *et al.*, 2008; Woods & Black, 2008) - but only a few of them truly dealt with indirect land-use change GHG emissions as presented by Searchinger and none proposed an alternative way of counting them.

However, it seems that agrofuels' indirect impacts were thought to be sufficiently serious since the 'Gallagher review' that synthesised all debates on iLUC in July 2008 asked for a slowdown in the growth of agrofuels (RFA, 2008b). Whereas the original RTFO agrofuel blending targets by volume were 5.3% for 2010-2011, the Gallagher review was convincing enough to result in a substantial decrease in blending targets from 2009-2010 and an extension of the 2010-2011 target to 3 years later (cf. following figure):

Table 37: Evolution in agrofuel blending targets in the UK (by volume)

	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Original RTFO targets (April 2007)	2.6%	3.9%	5.3%			
Gallagher proposed targets (July 2008)	2.5%	3%	3.5%	4%	4.5%	5%
Amended RTFO targets (April 2009)	2.6%	3.4%	3.6%	4.2%	4.7%	5.3%

Source: The Renewable Transport Fuel Obligations Order 2007[35], the Gallagher review (RFA, 2008b) and the Renewable Transport Fuel Obligations (Amendment) Order 2009[36]

[35] Cf. http://www.legislation.gov.uk/uksi/2007/3072/contents/made

In the UK, the agrofuel policy thus seemed to closely adapt to the evolution of the debate on agrofuels and take the controversy on their iLUC GHG emissions seriously enough to dramatically decrease the RTFO agrofuel blending targets.

However, since then, there has not been much novelty in the debate on indirect GHG emissions. A report commissioned by Friends of the Earth that came out in April 2009 showed with a simple model and basic assumptions that most agrofuels sold in the UK under the RTFO had higher GHG intensities than their fossil fuel equivalents when their indirect land-use change GHG emissions were taken into account (Kaliakatsou *et al.*, 2009). But the results of this report were not really further debated by the RFA that still does not include iLUC GHG emissions of agrofuels in its methodology or default values.

In June-July 2009, the European Commission opened a pre-consultation on 'indirect land-use change', the goal of which "was to seek views on possible elements of a policy approach in addressing ways to minimise the impact of indirect land use change" (European Commission, 2009c).

As a response to this consultation, the UK Government acknowledged the importance of iLUC and recommended the use of an iLUC factor in that it would be "the most effective tool for differentiating between 'good' and 'bad' [agro]fuels" and also recommended the use of bonuses for agrofuels that "have really positive indirect impacts, like making land more productive and reducing the need to dispose of waste"[37].

Then, a report showing that agrofuels made from co-products such as tallow (it is not generally a 'waste' since it may have uses) and molasses also had indirect impacts (Brander *et al.*, 2009) - and thus higher GHG intensities when their indirect GHG emissions were taken into account - was published in November 2009 but default values of agrofuels made from these feedstocks were not modified in the RTFO reports. Therefore, by-products are still considered to bring very good GHG emission reductions.

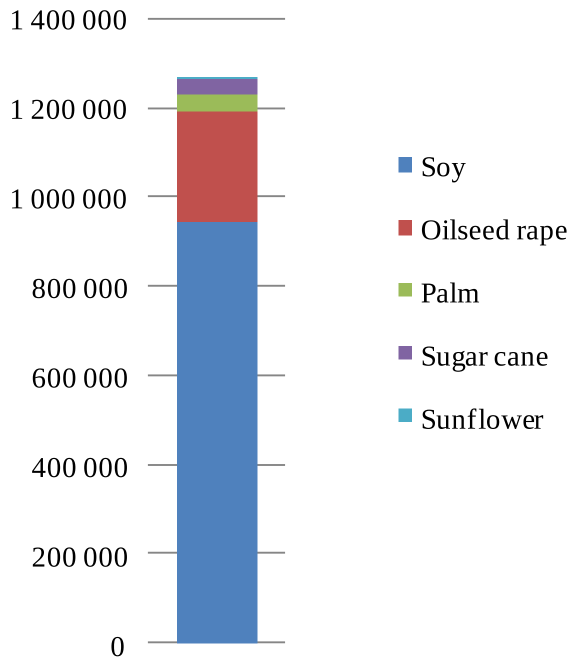
Finally, it is interesting to note that the estimated area of foreign land to supply agrofuels to the UK was calculated in the annual report of the RFA on Year 1 of the RTFO (RFA, 2010d). According to the RFA, **1.27 million ha of international land were needed during year 1 of the RTFO to supply imported agrofuels in the UK.** According to DEFRA's figures **this corresponds to more than a fourth of the land area for arable crops in the UK in 2009**

[36] Cf. http://www.opsi.gov.uk/si/si2009/draft/ukdsi_9780111473665_en_1
[37] Cf. http://ec.europa.eu/energy/renewables/consultations/2009_07_31_iluc_pre_consultation_en.htm

(DEFRA, 2010). This land was calculated for the 84% of all agrofuels (by volume) that come from feedstocks other than those classified as 'by-products'.

Most of that land need was linked to the consumption of soy agrodiesel consumption - especially soy from the US (716,000 ha) and Argentina (211,000 ha) - then rape methyl ester (mainly from Germany with 114,000 ha) and to a lower extent palm, sugar cane and sunflower (cf. following figure):

Figure 70: Amount of land needed for the production of agrofuels imported in the UK in 2008-2009 (in ha)



Source: Personal graph with data from RFA (RFA, 2010d)

However, it should be noted that these figures do not take account of the use of co-products produced at the same time as agrofuels and for which a share of the land use should be attributed. Taking account of co-products would lead to lower figures for land needs since for instance soy oil is sometimes considered as a co-product of soymeal production (Centrec Consulting Group, 2008) because only a small fraction of soybeans crushing is soybean oil while the majority of the product is soymeal (mainly used as animal feed). .

Thus, it seems that the issue of iLUC is rather well understood in the UK although its GHG implications are still not measured nor included in British agrofuel policies.

5.3 The French agrofuel policy is opaque and misguided

As seen in section 5.1, there is to date a serious lack of transparency on how agrofuel blending by energy content is calculated in the seven French reports that were sent to the European Commission, which makes it difficult to check whether the official energy blending of agrofuels in France is correct. However, our study showed that the actual agrofuel energy blending in total transport fuels in France is lower than that presented by French authorities, especially for agroethanol.

As for the UK, it was seen that despite several problematic choices of GHG emission reduction default values and some serious anomalies in RTFO reports, the RTFO made data on agrofuel consumption by feedstock, country of origin and previous land-use very transparent (within the limit of what was reported by agrofuel suppliers) and easily available.

5.3.1 No official data on the origin of agrofuels consumed in France

This situation is very different in France, where there has been no official data on agrofuel consumption by feedstock, by country of origin or by previous land use since 2004 despite growing international doubts on agrofuels' environmental benefits.

Until 2004, data on land use for agrofuel production for the French market was easily available since all feedstocks were grown on declared industrial set-aside lands (Hénard & Audran, 2003). Until 2003, official figures thus existed and showed that land use for agrofuel feedstock production was dominated by oilseed rape (for agrodiesel production) while some wheat and sugar beet were cultivated for ethanol production (Hénard & Audran, 2003).

Since then, it has been difficult to know the origin of agrofuels consumed in France (by feedstock, by country of origin and by previous land use) as there is no known official data from the French authorities on these issues. Nevertheless, according to Julien Turenne from the French Ministry of Agriculture (Turenne, 2008), 1,120,000 ha of cropland were used for the production of agrofuels in France in 2007:

- 990,000 ha of oilseeds for agrodiesel (90% OSR and 10% sunflower);
- 130,000 ha for agroethanol (100,000 ha of wheat and 30,000 ha of sugar beet).

Although not mentioned, all feedstocks for agrofuel production cited above were probably mostly cultivated for the production of agrofuels for French consumption.

As for 2009, in an interview with Marie-Cécile Hénard from the US Embassy in Paris, Mrs. Hénard stated that agrofuel experts usually thought that in 2009, 80% of agrodiesel consumed in France came from OSR, 10% from sunflower, 5% from palm and another 5% from soy oil while it was more difficult to know feedstocks for agroethanol. Karine Brûlé (also interviewed) from the French Ministry of Agriculture agreed on the difficulty in finding data on the origin of agrofuels consumed in France but agreed on the figures mentioned by Mrs Hénard on agrodiesel. Regarding agroethanol she simply stated that hypotheses laid in a 2007 report by the French Interprofessional Office for Main Crops ONIGC (35% from sugar beet, 51% from wheat and 14% from maize) (ONIGC, 2007) were probably close to reality since they relied on projected governmental agreements to agrofuel production units.

However, French governmental agreements are attributed to agrofuel production factories, not to areas of agrofuel feedstock production, and there is no obligation for agrofuel factories to produce agrofuels only from agrofuel feedstocks from their surrounding regions.

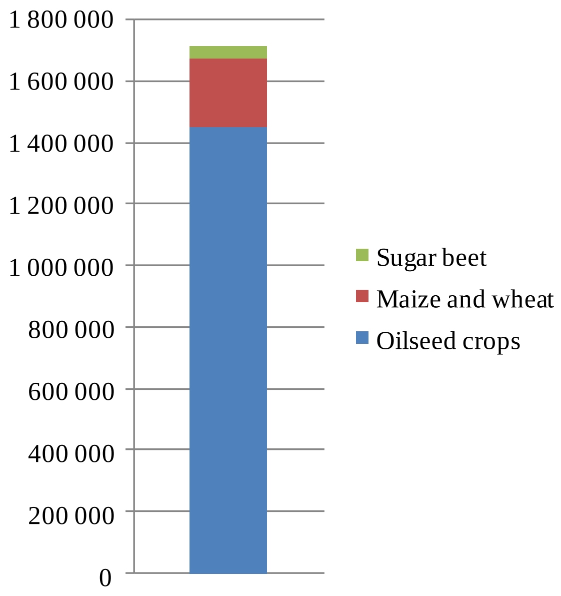
Thus, without any official data it is difficult to know for sure what the feedstocks of agrofuels consumed in France are as well as where they come from, even though most say they are mainly French and EU crops with only some overseas imports.

It should be noted that the French NGO *Résau Action Climat France* (RAC-F) refers to a figure of 30% of agrodiesel consumed in France coming from soy oil (25%) and palm (5%)[38]. This figure was also mentioned by other interviewees but is difficult to prove because of the lack of transparency from the French agrodiesel industry, which often claims that French agrodiesel is made in France but forgets to mention that its feedstock is partly imported.

According to its hypothesis of ratio of agrofuel feedstocks and the calculation for expected crop yields, the 2007 ONIGC report cited above (ONIGC, 2007) estimated that the land needs for agrofuels production for the French market in 2010 would look like what is shown in the next figure:

[38] Cf. http://www.rac-f.org/Agrocarburants-les-interets-des.html

Figure 71: Projected domestic land need for the 2010 French agrofuel consumption (in ha)



Source: Personal graph made with data from ONIGC (2007)

Not taking account of the undefined amount of agrodiesel that was expected to be imported (lower than 20% of total 2010 French agrodiesel projected consumption according to ONIGC), the projected area for agrofuel production from France and for France was calculated to be just above 1,700,000 ha, which correspond to about **10% of French arable land area** according to latest official figures (Agreste, 2010). However, it was detected in some RTFO reports that some agrofuels from French feedstocks were sold under the RTFO. Therefore, agrofuel feedstocks cultivated in France can also be converted into agrofuels sold to other countries and thus there might be more land than shown above for agrofuel production in France.

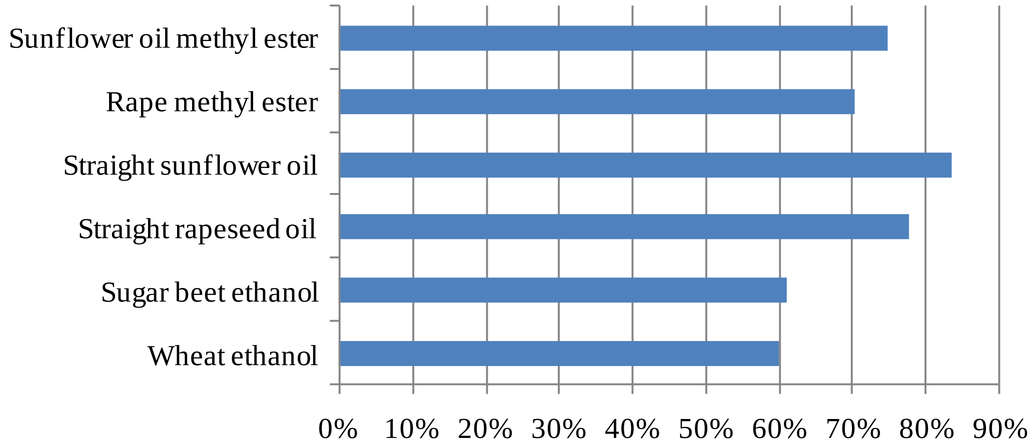
However, it should be noted that the cultivation of these feedstocks also leads to the production of co-products (such as rapemeal and DDGS), which can substitute for today's imported animal feed, for example soymeal from South America (Billon *et al.*, 2008) and thus reduce the net amount of land for agrofuel production.

5.3.2 An agrofuel policy based on the results of a highly controversial report

Although the French support to agrofuels is partly acknowledged to be a support to French farmers (Premier Ministre, 2005; Tréguer, 2008), this promotion has also been extensively justified on the basis that French agrofuels would show **considerable GHG emission reductions** compared with fossil fuels (Pasty, 2004; Delécrin, 2005; DGEMP, 2006; Douaud & Gruson, 2006; Prost *et al.*, 2006; Ministère de l'Agriculture et de la Pêche, 2007). Such allegations have been based for several years on the findings of one single report made in 2002 by the consultant firm Ecobilan for the two public bodies ADEME (French Agency for the Environment and Energy Management, linked to the Ministry of Ecology) and DIREM (French direction of energy and mineral resources, linked to the Ministry of Economy and Finance).

This single paper was probably the best (though highly controversial) advertisement for French agrofuel producers. Etienne Poitrat from ADEME indeed considers that the 2005 French national plan on agrofuels aiming at reaching 7% agrofuels by 2010 was launched based on the good results of GHG profiles of French agrofuels presented in this very report (Salmon, 2008). According to this study, GHG emission reductions enabled by agrofuels ranged from 60 to more than 80% compared with fossil fuel equivalents (cf. following figure):

Figure 72: GHG emission reductions of French agrofuels according to Ecobilan 2002



Source: Personal graph made with data from Ecobilan (2002a)

There is to our knowledge no other study that shows such high GHG emission reductions than those found by Ecobilan (cf. chapter 4 section 4.1.4).

Considering the very favourable GHG emission reductions calculated by this report, it would have been expected that the methodology used to obtain such results was made publicly available. However, only the executive summary of this report (Ecobilan/PriceWaterhouseCoopers, 2002a) (also available in English (Ecobilan/PriceWaterhouseCoopers, 2002d)) was available for several years, despite the growing controversy on agrofuels' environmental balance internationally. According to Xavier Chavanne from Paris University, the report (Ecobilan/PriceWaterhouseCoopers, 2002b; c) was eventually made available in its entirety only in September 2007 (**5 years after the executive summary was published**) probably thanks to repeated demands from the agrofuel specialist Patrick Sadones.

Now, one may wonder why this report was not published in its entirety earlier. The most obvious explanation for such delay lies in the fact that the methodology used in this study contained numerous biases that favoured agrofuels.

Following interrogations raised from the study of the 2002 report of Ecobilan, the NGO 'Energie en Normandie' (EDEN) published a critique which made the network of NGOs 'Réseau Action Climat-France' have a closer look at the very 2002 study (Réseau Action Climat-France, 2006). This resulted in the publication of a list of the numerous anomalies found in the 2002 Ecobilan report by Patrick Sadones (Sadones, 2006b). The following is a non-exhaustive list of some of the main anomalies:

- the use of **mass allocation** of GHG to co-products (chosen by Ecobilan) is not adapted to agrofuels since agrofuels' production precisely consists in separating the parts of the plant with the highest energy density to those with the lowest energy density by mass. While this type of allocation is valid for petroleum products (because they have similar energy densities), it largely favours agrofuels (Benoist, 2009). Sadones also reminds us that mass allocation has not been used in any other agrofuel study;
- some calculations have favoured agrofuels by attributing **abnormally high GHG burden to co-products**;
- **N_2O emission factors are underestimated**.

NB: It should also be noted that iLUC GHG emissions were ignored in the 2002 Ecobilan report but this is understandable since the debate on their impacts only appeared after Searchinger's 2008 paper.

However, the same consulting firm Ecobilan was commissioned by ADEME once again in 2006 to compare its 2002 study with an earlier version of the CONCAWE study than that extensively mentioned in previous chapters (Edwards *et al.*, 2007a) and a 2002 study by General Motors associated with some of the major oil companies.

Interestingly, in this 2006 report (Ecobilan, 2006), Ecobilan justifies its choice of mass allocation in the 2002 study by the fact that it is the same allocation rule than that it chose for oil products to which agrofuels were compared. Ecobilan then criticises the other studies for choosing system expansion for agrofuels and energy allocation for the oil products to which they are compared. However, Ecobilan does not clearly mention that the results of GHG intensity of fossil fuels were similar whatever the choice of allocation while mass allocation for agrofuels led to very favourable results of GHG intensity for agrofuels compared with those obtained by using system expansion.

Moreover, Ecobilan criticises other studies for having figures for N_2O emission factors with too much uncertainty and congratulates its 2002 study for choosing direct emission factors from data measured from British soils (Skiba *et al.*, 1996). However, it fails to acknowledge that N_2O emissions should also include 'indirect' emissions (which we call 'secondary' and 'off-site' emissions in chapter 3) and fails to acknowledge that N_2O emission factors are by their essence extremely dependant on numerous variables (cf. chapter 2 section 2.2.7), which might be very different in average French fields to those studied by Skiba.

Finally Ecobilan claims that since its 2002 study was funded by public sector offices, it must be independent contrary to GM and CONCAWE studies (which were made by experts from the car and the oil industry) and also congratulates its 2002 study for including experts from the agriculture and agrofuel fields in its steering committee. However, considering all the above biases in the methodology chosen in the 2002 Ecobilan report leading to unrivalled low GHG intensities, there are reasons to think that maybe French authorities and companies that have interests in the promotion of agrofuels may have had some influence upon the choice of methodology found in this study. As a matter of fact, it was very intriguing to see that people at Sofiprotéol (the financial branch of the main French agrodiesel producer Diester Industrie) advised me to get in touch with the people - acknowledged to be very 'friendly' - that had performed the 2002 study so positively with regard to agrodiesel GHG emission reductions.

Interestingly, a 2007 paper from the French Ministry of Agriculture entitled "Biofuels, a great opportunity for our country" uses Ecobilan's 2002 reports findings and then insists on the merit of Ecobilan's 2002 study for (contrary to many other studies) being consistent in its choice of co-product allocation, as if this made the report objective (Ministère de l'Agriculture et de la Pêche, 2007). However, this is by no means a valid justification of the supposed objectivity of Ecobilan's 2002 report.

5.3.3 A no less controversial update of the 2002 Ecobilan study

In order to update the 2002 Ecobilan report, the environment consulting firm Bio Intelligence Service (BioIS) was commissioned to elaborate - in consultation with numerous stakeholders - a methodological frame of reference to be able to perform an update of agrofuel LCAs.

This time, the main differences of methodology choices with the 2002 Ecobilan study are (Bio Intelligence Service, 2008a) (executive summary available in English (Bio Intelligence Service, 2008b)):

- the choice of the use of energy allocation for by-products;

- the choice to use the IPCC Tier 1 N_2O emissions factors.

It is interesting to note that among the 39 stakeholders who participated in this study, 2 came from NGOs (Patrick Sadones and Pierre Perbos from RAC-F).

The main drawbacks of this new methodological frame of reference are that:

- it uses energy allocation of GHG emissions to co-products whereas most international studies favour system expansion that seems less arbitrary even if it requires modelling and can also be made in a subjective way;
- it uses the IPCC Tier 1 methodology for N_2O emission factors although these factors are at the time criticised for being too low (cf. chapter 3 section 3.2.7);
- regarding iLUC it merely states that there are too many uncertainties on its associated GHG emissions and recommends to go more into depth when more research on this field is available.

After this methodological frame of reference was determined, BioIS was commissioned to perform an update of LCAs of several agrofuels.

However, this update took a long time to complete. Whereas it was expected to be published in June 2009, its release was delayed - due to numerous corrections and demands for more transparency suggested by the critical review made by a panel from the Swiss environment consulting firm Ecointesys (Boucher *et al.*, 2009b) - to mid-September 2009 at the occasion of the national "week of mobility" (Chesnais, 2009) and then again to October 2009. After 4 months of delay, it was eventually made available on the ADEME website, but was removed after only few days following harsh criticisms from NGOs (Fabrégat, 2009; Roussel, 2009), with just the statement that "additional complements were needed" (Verney-Caillat, 2009).

We managed to keep a copy of this removed report (Bio Intelligence Service, 2009), which shows agrofuels with extremely favourable GHG emission reductions compared to fossil fuels.

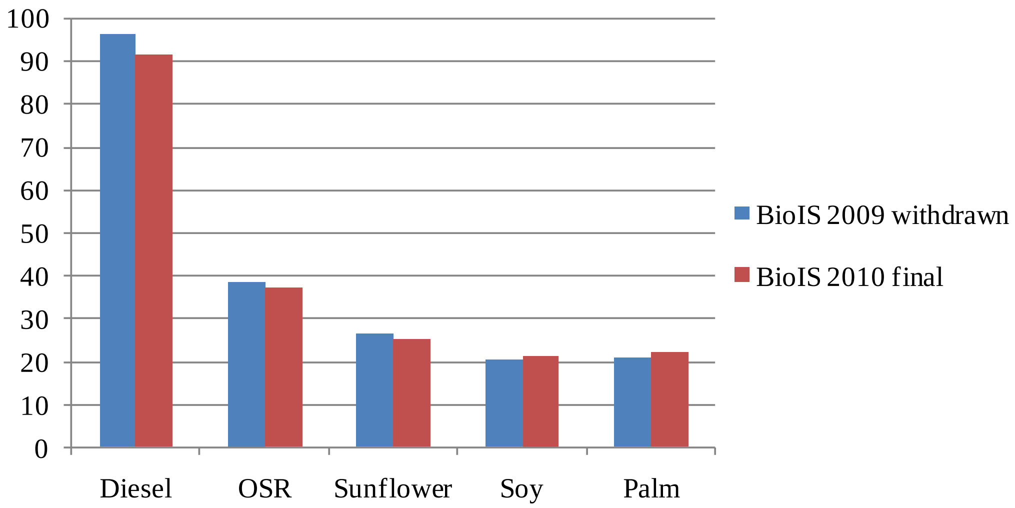
Apart from questionable methodology choices (energy allocation is arbitrary and has no logical justification), once again, numerous anomalies were found in this intermediate report, particularly the GHG burden attributed to co-products is thought to be too important (especially for sugar beet pulps), which excessively favours agrofuels (Sadones, 2009). This point is actually an important remark from the second critical review that was performed by the same Ecointesys panel (Boucher *et al.*, 2009a).

Moreover, the default GHG intensities of fossil fuels in this withdrawn report are much higher than those commonly used for European fossil fuels (cf. chapter 4 section 4.2.5), which provoked the anger of oil companies.

An updated final version (Bio Intelligence Service, 2010) was eventually released in April 2010 (it is still available on the ADEME website), that is 6 months after the former withdrawn version and 10 months after the date it was supposed to come out, with more realistic GHG figures for fossil fuel GHG intensities. But this final version still attributes excessive GHG burden to co-products in order to favour agrofuels (Sadones, 2010), uses N_2O emission factors lower than default values of IPCC Tier 1 (contrary to the recommendations of the 2008 BioIS frame of reference and even though IPCC default values are thought by many to be too low as well) and of course still uses energy allocation for co-products. Moreover, although some work is done to calculate agrofuels' iLUC GHG emissions, results of iLUC GHG emissions are not included in the conclusions of the report. Finally, on top of these weaknesses, differences were found in the GHG results between the removed version and the final version of the report.

As can be seen in the following figures, GHG intensities of agrofuels slightly changed between the 2009 and 2010 reports (especially for agrodiesels for which GHG intensities are nearly the same), while GHG intensities of fossil references (diesel and petrol) were dramatically reduced:

Figure 73: Changes in GHG intensities of diesel and agrodiesel (in gCO_2e/MJ)

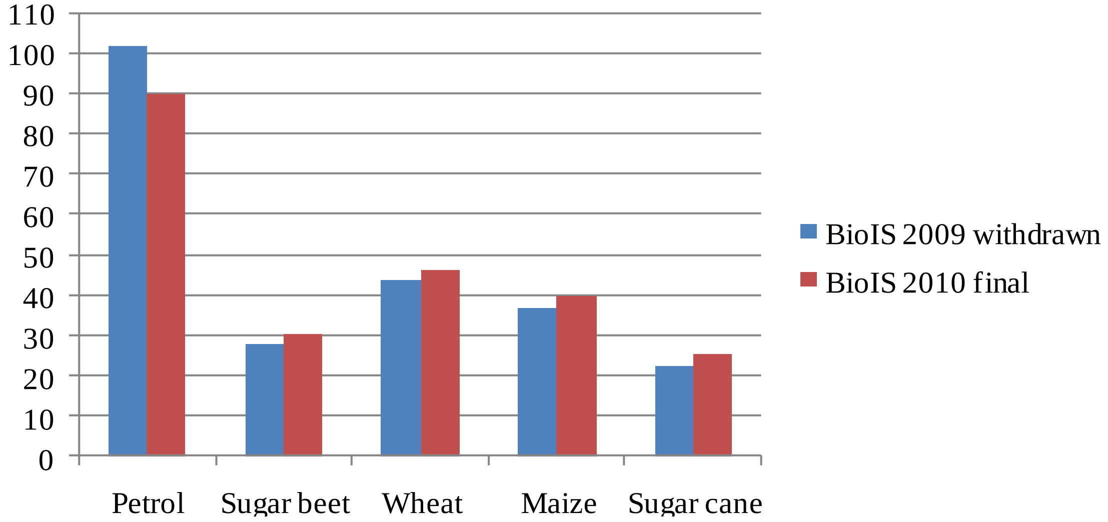


Source: Personal graph made with data from BioIS 2009 and BioIS 2010

It is interesting to note that only the GHG intensities of agrofuel crops grown in France were reduced between the 2009 and the 2010 reports while those of imported feedstocks (soy and palm) increased.

As for petrol, its GHG intensity was reduced by 11% between the two reports while interestingly the GHG intensities of all types of agroethanol were increased (cf. following figure):

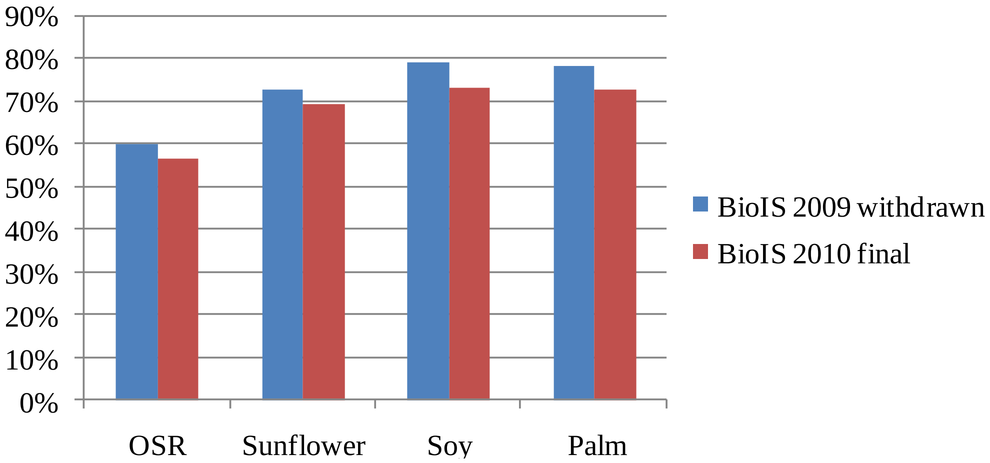
Figure 74: Changes in GHG intensities of petrol and agroethanol (in gCO_2e/MJ)



Source: Personal graph made with data from BioIS 2009 and BioIS 2010

These changes had impacts on the GHG emission reductions calculated in the second report (cf. following figure):

Figure 75: GHG emission reductions of agrodiesel compared with diesel

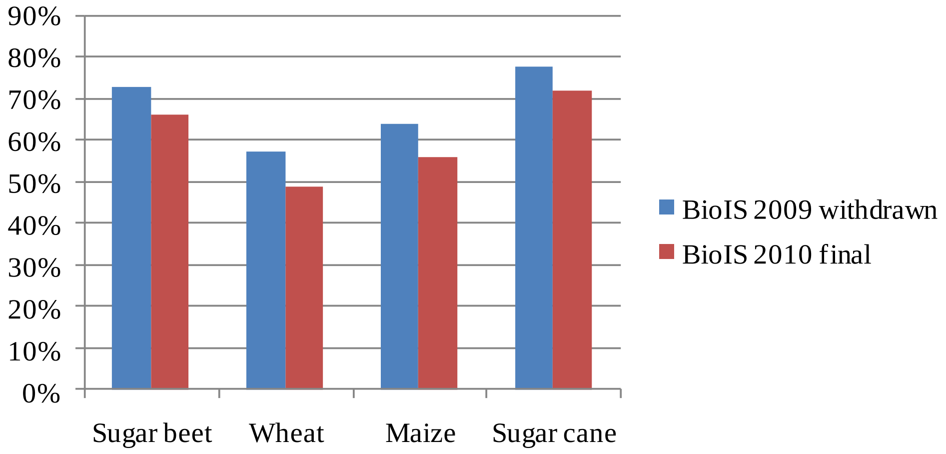


Source: Personal graph made with data from BioIS (2009; 2010)

It should be noted that results of GHG emission reductions decreased for all types of agrodiesel, but particularly for soy and palm (imported feedstocks).

As for agroethanol, GHG savings decreased approximately in the same proportion for all feedstocks (cf. following figure):

Figure 76: GHG emission reductions of agroethanol compared with petrol



Source: Personal graph made with data from BioIS (2009) and BioIS (2010)

The change of fossil fuel reference GHG intensities to more usual values in the second report thus contributed to the reduction of calculated GHG emission reductions of all agrofuels compared to those found in the first (withdrawn) report of BioIS.

However, this update of the controversial 2002 Ecobilan study still lacks transparency and still uses numerous methodological biases that excessively favour agrofuels, particularly those from French feedstocks. This partly explains why the BioIS figures for French agrofuels are still among the best (in terms of GHG emission reductions) found in the literature.

Since the calculated GHG emission reductions provided by ALL agrofuels consumed in France (which are then used as official values) have constantly been artificially above the 35% requirements of the 2009/30/EC Directive (at least when iLUC is not taken into account), it is understandable that French authorities think that no official GHG emission reduction target is needed.

5.3.4 The concept of iLUC seems to be often misunderstood

Although agrofuels consumed in France mostly came from feedstocks grown on industrial set-aside land in the first place, they started to compete with food production when a new European subsidy called “energy crop aid” came out in 2004. However, because of the rapid increase in agrofuel demand, only half of agrofuel feedstock cultivation area was industrial set-aside in France in 2006 (Guindé *et al.*, 2008). Then, following the tensions on food prices at the world level, set-aside was made no more compulsory in Europe in 2008 (Europa, 2007).

As a consequence, current first-generation French agrofuels made from crops such as OSR, sunflower, sugar beet, wheat or maize necessarily compete with food and thus partly cause iLUC (which needs to be determined by also taking account of co-products).

However, French agrofuels are often presented in ways that make people believe that they do not cause land-use change of any kind. For instance, the main French agrodiesel producer *Diester Industrie* claims on its webpage that there is no deforestation with French agrodiesel since “OSR and sunflower for agrodiesel only come from arable land or former set-aside lands […] and also since sustainability criteria implemented by the European Union will ensure that agrofuels imported do not come from deforested areas” [39]. However, such claim ignores indirect land-use change that is associated with agrofuels produced from French arable land.

Moreover, it is common in the French media to mention only direct GHG emissions from LUC, which stigmatises imported agrofuels (lemonde.fr, 2010). The little understanding of iLUC in France also lies in the fact that French agrofuel producers often knowingly make the confusion between LUC (which only happens for imported agrofuels according to them) and iLUC or present iLUC as something that is negligible and that only depends on policies of other countries (Le Loët, 2010).

However, it has been established that French imports of vegetable oils have recently sharply increased, and this is thought to be due to the development of agrofuels in France (DGDDI, 2008; Carrelet, 2009). Such increase in imports of oil may be a sign that crop displacement occurs due to the increase in production of agrofuels from French oil crops, which may in turn result in iLUC.

Nevertheless, President Sarkozy declared in an important speech that the backing of agrofuels needed to be re-examined but without challenging “today’s commitments” (Présidence de la République, 2007). This demonstrates at the highest level of governance support to agrofuels regardless of their environmental implications in terms of iLUC (since the targets of agrofuel blending will not be changed).

Consistent with this approach, in its response to the EC pre-consultation report on iLUC, French authorities favoured GHG bonuses to first-generation agrofuels from degraded land in Europe. However, they did stress the importance of increasing the stringency of sustainability criteria for agrofuels whose feedstock come from regions with risks of iLUC and declared themselves against an iLUC factor, except for imported feedstock (palm, soy and sugar cane). This response

[39] Cf. http://www.prolea.com/index.php?id=10627

demonstrates some confusion on and a misunderstanding of iLUC by the French authorities which nearly seem to say that European feedstocks cannot lead to iLUC[40].

iLUC GHG emissions are calculated in Ecobilan's 2010 report, but the focus is more on the potential impacts of LUC on GHG intensities of imported crops (soy from Brazil and palm from Malaysia and Indonesia) or the potential iLUC impacts on the GHG intensity of US soy.

As for wheat and OSR (French crops), their GHG intensities are calculated for situations in which their associated feedstocks (DDGS and rapemeal respectively) substitute for soymeal that caused LUC (and thus with a very high GHG intensity), which results in very low GHG intensities for French wheat ethanol and rape methyl ester. However, the calculations do not consider iLUC due to the use of land for French agrofuel production, that necessarily displaces other crops and which would probably negate all benefits from the substitution of co-products by GHG-intensive soymeal.

Finally, near the end of the report, GHG intensities taking account of iLUC GHG emissions are calculated for RME and wheat ethanol. However, these calculations are made with iLUC GHG emissions that are poorly justified (LUC for OSR seems particularly low) and lead to results that show that agrofuels' GHG intensities with iLUC could exceed fossil fuel GHG intensities. However, BioIS managed to create an 'intermediate' scenario (in which forests are converted to perennial crops) for which GHG intensities of French agrofuels with iLUC are still below those of fossil fuels (Bio Intelligence Service, 2010).

In the summary of this study on the ADEME website it is acknowledged that LUC and iLUC GHG emissions "can negate agrofuels' GHG balance". However, right after, the following sentence - "on these bases, current use of agrofuels in France saves 5,440,000 tonnes a year of CO_2 in the atmosphere"[41] - is very paradoxical and seems to totally ignore LUC and iLUC GHG emissions.

5.3.5 Potential reasons for differences between French and UK agrofuel policies

The promotion of agrofuels is done in a much more favourable way in France than it is in the UK. This is probably linked to the fact that most agrofuels consumed in France come from French feedstocks so far, while most agrofuels consumed in the UK come from feedstocks grown overseas. **Promoting agrofuels in France could thus be, in part, a way to promote French agriculture**.

[40] Cf. http://ec.europa.eu/energy/renewables/consultations/2009_07_31_iluc_pre_consultation_en.htm
[41] Cf. http://www2.ademe.fr/servlet/KBaseShow?sort=-1&cid=96&m=3&catid=23698

The agriculture sector is indeed a strong economic and therefore political power that is about three times more important in economical terms in France than it is in the UK (Agreste, 2010). Moreover, it should be noted that the agriculture area of the UK is much more limited than that in France.

The fact that agrofuels consumed in France mainly come from France while agrofuels consumed in the UK mostly come from overseas may also be a reason why the UK authorities have tried for several years to ensure that agrofuels consumed in the UK do not cause direct land-use change ('previous land use' is part of the data asked by the RFA to agrofuel suppliers), long before the French authorities started to take a look at LUC.

Moreover, once the question of iLUC entered the agrofuel debate, it was quickly understood and somehow taken into account by UK authorities - which reduced the agrofuel blending target - probably helped by the fact that there was little economic interest for the UK to support agrofuels from the beginning.

On the opposite, French reports that calculated agrofuels' GHG emissions only started to include LUC GHG emissions in 2008 (Bio Intelligence Service, 2008a). LUC has not been considered as a big issue in France because most agrofuels sold in France have been domestically sourced so far. As for the iLUC notion, it seems poorly understood in France, probably because French agrofuel and agrofuel feedstock producers do not want to recognize the connection between agrofuels' feedstocks grown in France (which are the main agrofuels consumed in France) and international iLUC. There is a general false impression among many French people that iLUC is the same as LUC (idea that "LUC GHG emissions can only come from agrofuels produced overseas") so that agrofuels from French feedstocks are often not even considered as causing iLUC.

Other factors that may explain the differences in the French and British agrofuel policies are the following:

- the agrofuel sector is very well established in France (particularly the agrodiesel company Diester Industrie) and has benefited from large subsidies for several years.
- the UK has one organisation that centralises information on agrofuels (the RFA) while information is scattered between numerous administrations in France (Ministries of Ecology, Finance, Agriculture, customs, ADEME, etc.);
- environment NGOs seem to have more influence in the UK than in France.

Conclusion

The critical comparison between the contexts of agrofuels in France and in the UK made in this chapter leads to several interesting conclusions.

It was identified that French authorities are very favourable to agrofuels (especially to French agrofuels) despite a serious lack of transparency in reports on which French policies base their perception of agrofuels' GHG balance. This lack of transparency is also found in the way agrofuel data are presented by French authorities. Moreover, our research showed that the energy share of agroethanol in petrol-like fuels declared by the French authorities was overestimated due to some mistakes in the calculations, which are difficult to find precisely because of the general lack of transparency.

On the contrary, even though the UK agrofuel policy is far from being perfect, numerous more transparent studies on how to take account of agrofuels' environmental impacts were released and the policy seems to be based on several reports that are publicly available. The RTFO also took account of considerable work on iLUC (which was used as the main argument to reduce the agrofuel blending targets in the UK) even though this last issue is still not included in RTFO GHG methodologies.

These case studies are a good example of a situation where science is used for political/economical purposes. In the UK, where agrofuels are mostly imported and where little economic benefit is expected from agrofuels, the environmental balance of agrofuels has been assessed to be too uncertain to continue a policy that initially aimed at largely increasing agrofuel consumption (though below EU recommendations).
On the contrary, in France where agrofuels consumed mostly come from French feedstocks, the environmental balance of agrofuels has constantly been artificially improved in order to justify the promotion of agrofuels (above EU recommendation).

Economic and political interests in agrofuels thus seem to be inversely correlated to the transparency of the official reports published on their subject in France and in the UK. The 'scientific' conclusions on the environmental balance of agrofuels are also highly dependent on the interest of both countries in promoting agrofuels or not.

Chapter 6:
Conclusions and recommendations

"Despair is the conclusion of fools."

Benjamin Disraeli (1804-1881), British Prime Minister and writer

"The biggest impediment to action against climate change is no longer climate change denial. It is greenwash!"

George Monbiot, Guardian columnist, Imperial College CEP Seminar Series, 15th February 2007

Introduction

This last chapter presents the main findings of this thesis, suggests some recommendations for policy-makers as well as for individuals and finally presents the limitations of this thesis and proposes topics for further work.

6.1 Summary of the main findings and contributions of this thesis

This section presents the main findings of this research, which are considered to add up to new knowledge in the agrofuel area.

From chapter 2:

- The wording 'biofuel' is inappropriate and misleading for most current transport liquid biomass-derived fuels. The wording 'agrofuel' was found to be more neutral and more adequate for such fuels.
- Greenwashing arguments and terminology are commonly used by stakeholders from the concerned industries but also in the politics for the promotion of agrofuels.
- Although it is recognised that only the agroethanol share is 'renewable' in agro-ETBE and agro-MTBE, agrodiesel is often assumed to be 100% 'renewable' even though about 11% of its mass usually come from fossil-fuel derived methanol.
- The terminology 'renewable' seems inappropriate to describe agrofuels as regards the way they are currently obtained.

From chapter 3:

- Agrofuels usually are a small output from their production chains.
- Agrofuels' environmental impacts are numerous: direct primary, secondary and tertiary; indirect linked to iLUC and not linked to iLUC, and affect all environmental areas of concern, not only GHG emissions.
- Several official data on transport GHG emissions consider that agrofuels' GHG emissions are equal to zero in transport, not because agrofuels are GHG-neutral but because they attribute their GHG emissions to other sectors than transport.
- For most agrofuels, there are serious doubts that GHG benefits are brought compared with fossil fuels when iLUC is taken into account or even if it happens that the actual N_2O emission factor is higher than that currently used in calculations.
- The assessment of indirect land-use change associated with a specific land for agrofuel production is highly uncertain.
- Many factors already put pressure on land use, such as the growing world population, increasing meat and animal product consumption (which are more land-intensive than vegetable products in general), desertification, urban sprawl, cropland soil exhaustion, etc. Agrofuels are a new factor that adds up to other types of pressure on land use.
- Indirect impacts of agrofuels other than iLUC GHG emissions are so far ignored.

From chapter 4:

- Agrofuels' certification schemes capture only some direct environmental impacts of agrofuels (direct secondary and tertiary are not taken into account). Such oversimplification of agrofuels' environmental impacts gives irrelevant results for their actual environmental balance.
- Agrofuels' certification schemes are not stringent enough for most certified agrofuels to have low direct non-GHG environmental impacts. Thus, agrofuel certifications may sometimes appear as a means to legitimise intensive unsustainable farming practices.
- Agrofuels' GHG emission default values or GHG emission reduction targets in agrofuel certification schemes rely on too many choices and assumptions to be easily compared.
- All methodologies for the calculation of agrofuels' GHG emissions rely at some point on methodological bias (choice of co-product treatment, choice of baseline, choice of boundaries, choice of method for the annualisation of LUC GHG emissions, etc.) or assumptions based on uncertain science (choice of N_2O emission factor, iLUC GHG emissions, etc.).
- The choice of global warming potentials over 100 years (Kyoto Protocol recommendation) seems inconsistent with the choice of annualisation of LUC GHG emissions over 20 years.

- Apart from reduction of land needs thanks to changes in consumption patterns and dietary habits of consumers, few solutions seem to prevent current agrofuels from causing iLUC.
- Current agrofuels may be seen as an incentive for citizens not to change their personal transportation choices and therefore habits.
- In most cases, agrofuels' potential direct GHG benefits are currently only possible if co-products are used as animal feed supposed to displace imported feed (for instance soymeal in Europe). Thus, agrofuels' direct GHG emission reductions are somehow artificially gained from the livestock sector, which is known to already be a major GHG contributor.
- According to most scenarios, agrofuels' rapidly increasing consumption will not be sufficient to compensate for the increase in transport energy demand. Thus, agrofuels only add up to growing fossil fuel demand, they do not really substitute for fossil fuels at the world level.
- Discussing agrofuels' environmentl sustainability does not make sense when agrofuels are not assessed in the general context of increasing land needs and increasing transport energy demand.
- Considering current scenarios of rapid increases in transport energy demand (mostly met thanks to oil consumption), even best theoretical agrofuels (ideal zero-carbon agrofuels) do not allow a reduction in transport's growing GHG emissions.

From chapter 5:

- The RTFO reports make agrofuels' consumption in the UK relatively transparent, with information of agrofuels' consumption by feedstock or by country of origin presented when available. However, the default values used to assess agrofuels' GHG emission reductions do not take account of indirect impacts and are arbitrarily chosen in ways that make some types of agrofuels with specific unreported data have lower default values than those with reported data. The official estimate of average GHG emission reduction enabled by agrofuels consumed in the UK thus appears to be artificially high.
- The RTFO is designed in such a way that it incentivises fuel suppliers not to report previous land use when conversion of forest or grassland occurred.
- The French authorities increased agrofuel blending targets for France based on extremely favourable GHG emission reductions calculated in a 2002 report of Ecobilan (Ecobilan/PriceWaterhouseCoopers, 2002b). However, this report lacks transparency, contains numerous flaws and methodological biases that favour agrofuels and was not made public in its entirety for nearly 5 years.

- French reports to the European Commission on the implementation of the 2003/30/EC Directive are not transparent, contain numerous flaws and overestimate the agroethanol blending by energy content in France because of a wrong choice of LHV for agroethanol contained in agro-ETBE.
- There has been no transparency on the origin (feedstock, country of origin or previous land use) of agrofuels consumed in France since 2004.
- The latest French reports on agrofuels' GHG emissions used methodological biases that artificially improved agrofuels' GHG balance. In a withdrawn version of the latest 2010 report, fossil fuel GHG intensities were even exaggerated in order to improve agrofuels' GHG emission reduction compared with fossil fuels. Finally, the conclusions of the last official report do not take account of agrofuels' iLUC GHG emissions.
- There is little debate on agrofuels' iLUC GHG emissions in France, resulting in a general misunderstanding of this concept. Moreover, some stakeholders of the French agrofuel industry take advantage of this confusion to promote agrofuels from French feedstocks, claiming such agrofuels do not cause iLUC.
- The UK agrofuel policy used the pretext of to the evolution of the scientific debate on agrofuels' GHG implications to adapt its policy whereas France did not change its targets.
- 'Scientific' results on agrofuels' GHG balance are different between France and the UK. They actually match political aims of promoting French agriculture in one case, and of reducing forecast imports of agrofuels in the British case. Thus 'science' is dependent on political and economic conditions and used in a biased way for the justification of political objectives.

<u>Overall finding</u>:
While transport GHG emissions are increasing, agrofuels are brought in to reduce transport GHG emissions. However, agrofuels' overall GHG emissions are often comparable to or even worse than those of fossil fuels, not to mention other environmental impacts.

Therefore, agrofuels' increasing consumption may result in a higher increase in transport-associated GHG emissions than if fossil fuels continued to be used (nearly) alone. Due to increasing transport energy demand, even if agrofuels were GHG-neutral, they could at best only partly reduce the increase in transport GHG emissions.

Thus, agrofuels can be seen as a massive 'red herring' to transport GHG emissions.

6.2 Recommendations for policy makers

The following recommendations are addressed specifically to policy makers in 'developed' countries that currently favour increases in agrofuel blending.

- **Suspend agrofuel blending targets and subsidies for the production of agrofuels**

In view of the current uncertainties regarding agrofuels' actual environmental impacts, policies cannot reasonably continue to promote agrofuels on environmental grounds. There is no solid evidence that most agrofuels bring any GHG benefit compared to the fossil fuels they are supposed to replace. Moreover, agrofuels generally have larger non-GHG environmental impacts than fossil fuels, which are so far poorly assessed.

Thus the findings of this research call for a *suspension of agrofuel blending targets as well as subsidies to the agrofuel sector,* at least until such time as methodologies are proven to address key sustainability challenges associated with agrofuels, starting with GHG emissions.

- **Implement policies that aim at reducing transport energy demand**

In order to reduce transport GHG emissions, policies must aim at reducing transport energy demand since until now there is no credible low-carbon energy source that is available at a large enough scale for transport. Improving the efficiency of new cars or educating drivers on ways to reduce fuel consumption by changing driving styles are important but they only represent one small step because they can be offset by a rebound effect.
In order to avoid such a rebound effect, transport policies may need to progressively increase taxes on energy to achieve transport energy demand reduction. It is acknowledged that such measures might be unpopular but political courage is thought to be needed in times of major environmental crises. On the other hand, transport policies should promote another vision of transport, with more public transport, incentives for changes in car use (more car clubs or car sharing schemes), as well as incentives to cycle or simply walk. Lifestyles that require less transport should also be encouraged (tele-commuting, tele-conferences, etc.).

It is interesting to note the historic precedent of the US Government that tried to persuade its people to reduce their oil consumption during the Second World War (cf. following figure):

Figure 77: When You Ride Alone You Ride With Hitler!

Source: Poster by Weimer Pursell (1943), printed by the Government Printing Office for the Office of Price Administration, National Archives and Records Administration
(Cf. http://www.archives.gov/exhibits/powers_of_persuasion/use_it_up/images_html/ride_with_hitler.html)

Changes comparable to those required by what was a 'war effort' at the time seem to be necessary nowadays because of the urgency of actions needed in regard to climate change. However, the forthcoming consequences of peak oil on oil prices might be more efficient than climate change arguments to reduce transport energy demand.

- **Reduce subsidies to intensive farming and encourage conversions to more environmentally-sound types of agriculture for the production of agrofuel feedstocks**

With agrofuels, transport policies cannot be separated from agriculture policies any longer. A thorough study of agrofuels makes them appear as a magnifying mirror of all problems linked to current agriculture. It seems illogical to promote agrofuels on environmental grounds and at the same time allowing unsustainable agricultural practices for the cultivation of their feedstocks. Intensive farming requiring heavy use of machinery and agrochemicals does not take account of the life in the soil and leads to numerous adverse impacts on biodiversity, soil, water quality, air quality, etc. Such farming practices should not be authorised for certified agrofuels because they cannot produce low-impact agrofuel feedstocks.

- **Reduce subsidies to the production of the most land-intensive types of food**

Since agricultural land use is such an important aspect of agrofuels, transport policies that promote agrofuels need to integrate the fact that meat and dairy production account for the largest use of agricultural land and are very land-intensive. Since agricultural land is limited worldwide, since crop production is probably already often above sustainable levels, and since alternative diets with lower meat and dairy consumption are possible - and even healthier according to numerous health studies gathered in T. Colin Campbell's 'China Study' (Campbell, 2006) - it seems that agrofuels' associated iLUC cannot be avoided while the production of agrofuels is increasing unless diets lower in animal products are encouraged. Thus, environmental policies that want to maintain agrofuels as part of their transport package must start to act in favour of a reduction of meat and animal product production (and consumption) for their environmental promotion of agrofuels to be consistent. Since meat and dairy industries are the recipient of very large subsidies (Holm & Jokkala, 2008), one first step could be to reduce subsidies to this sector.

- **Carefully examine second-generation biofuels before developing policies that promote them**

Policy-makers should also beware of the appeal of '2nd generation biofuels' (some of which are agrofuels, others being woodfuels, cf. chapter 2). They also lead to numerous environmental impacts that are poorly understood and for which more research is needed. The use of plant 'residues' might lead to soil exhaustion or increased needs in fertilisers for instance. Environmental impacts of removing plant residues from the ground should be carefully examined as well as potential risks of competition with other uses. Generally, the environmental impacts of any technological promise need to be clearly examined before we rush headlong to support it.

- **In the RTFO, agrofuels with unreported previous land use should have a default value that is equal to that of the worst case scenario**

British authorities should acknowledge that choosing favourable default values for agrofuels with unreported previous land use can lead to cheating and to an underestimation of the actual (direct primary) GHG emissions of such agrofuels. We recommend that agrofuels with 'unknown' previous land use get a severe GHG penalty.

- **French authorities should be more transparent in matters regarding agrofuels and must reduce their agrofuel blending targets**

French policy-makers must realise that the French agrofuel policy is not doing any good to the environment. They also need to understand that more transparency in the policy, in the reports, and in the availability of data on agrofuel consumption is needed. Policies with the level of opacity of the current French agrofuel policy and based on such voluntarily distorted presentations of reality are obsolete.

French farmers can legitimately receive public funds as financial help, but this should be for aims of more sustainable agricultural practices (conversion to organic farming or bio-dynamic farming for example or decrease in animal product production).

6.3 Recommendations to individuals

The debate on agrofuels can result in very positive leaps of consciousness. Indeed, challenging agrofuels' environmental expectations can lead us to ask ourselves such questions as:

- Can I modify the way consider transport? Can I reduce the use of my car?
- Can I modify my diet and reduce the share of land-intensive food such as meat and dairy?

It is up to individuals to take appropriate measures in order to make their lifestyles coincide with their aspirations. Indeed, it should be understood that policies cannot be expected to make things 'better' without a strong public support (cf. 'failures' of most international conferences such as the 2009 Copenhagen Summit). But people have the power to change themselves. As Gandhi said, "be the change you want to see in the world"!

The changes required from individuals in order to live more sustainable lives are challenging. However, they may bring more awareness and quality in life.

6.4 Limitations and further work

It was shown that agrofuels' environmental implications are extremely difficult to comprehend. Agrofuels' impacts affect all environmental areas of concern, from GHG emissions, to soil quality or biodiversity. Moreover, not only should their direct impacts (primary, secondary and tertiary) be taken into account but this research shows that their indirect impacts (associated to iLUC, but not necessarily) too should be taken into account in order to have a good understanding of agrofuels' overall implications on the environment.

Because knowledge is lacking for such assessments, more research is needed to understand better the overall environmental implications (direct and indirect) of agrofuels, particularly in relation to their GHG emissions. Moreover, rules need to be found in order to assess objectively the share of agrofuels' environmental impacts in their production chain, for instance by allocating in an agreed manner the environmental burden between agrofuels and their co-products.

Finally, as was mentioned in chapter 3, there has been so far no study of the indirect non-GHG environmental impacts of agrofuels. This is thus a totally new field of study in which research would be particularly worthy.

As was seen several times in this research, most of the directions followed by transport policies rely on supply-side solutions. There needs to be more research on how to integrate demand-side options in policies.

Finally, we need to have a more holistic approach when considering agrofuels' environmental implications as well as when looking for solutions for more sustainable transport. As for probably all environmental matters, interdisciplinary research is thought to be essential for agrofuels.

Final conclusion

It seems that humanity acts as if it had forgotten that the planet Earth is finite - limited amount of non-renewable sources of energy, limited amount of land, etc. - and lives in the illusion that the planet is boundless. All problems raised by agrofuels' development come at the right time to make us understand that a profound change in our consumption behaviour is needed as the planet cannot sustain any longer our increasing 'needs'. Since human imagination is infinite and since "imagination is more important than knowledge" (Albert Einstein), now is the time for humans to use their imagination to create a society where the choices of sources of energy and land use are more harmonious and sustainable.

Appendix

Appendix A: Compiled data of agrofuel consumption in the UK

In the following tables:

- 'Grass/Agr' means 'grassland in agricultural use';
- 'Neth.' stands for 'the Netherlands';
- 'Switz.' stands for 'Switzerland';
- 'By-prod.' stands for 'By-product';
- 'MSW' stands for Municipal Solid Wastes.

All data for which feedstock, country of origin or previous land-use were reported as 'unknown' are written in italic and purple in order to be more easily detected.

The data in the following tables are disaggregated data calculated from data found in monthly RTFO reports. Some calculated data of monthly sales are negative because in these cases the cumulative data of month N+1 were lower than cumulative data of month N in the RTFO reports. Negative data are highlighted in green.

It was calculated that the sum of positive data from some specific types of agrofuels sometimes offset calculated negative data. In these cases, positive and negative data exactly offsetting each other were highlighted in yellow.

Agrofuels from land that were grassland in agricultural use at the RTFO reference date are highlighted in orange.

Finally, data that were considered surprising in terms of quantity or in terms of quality (such as palm oil from France or Used Cooking Oil from Chile in March-April 2010) were highlighted in blue.

Table 38: Agrodiesel monthly consumption during the first semester of the RTFO

Feed-stock	Country of origin	Previous land-use	Apr-May 2008	May-June 2008	June-July 2008	July-Aug 2008	Aug-Sep 2008	Sep-Oct 2008
Oilseed rape	Canada	Cropland	367 017	4 472 503	2 542 928	4 455 160	1 918 939	
		Unknown	*181 637*	*4 079 370*	*2 291 657*	*-1 081 921*		
	Finland	**Grass/Agr**		**47 088**		**-47 088**		
		Unknown				*65 453*		
	France	**Grass/Agr**		**47 089**		**-47 089**		
		Unknown			*91 136*	*799 618*	*710 943*	*205 890*
	Germany	Cropland	5 329 357	8 139 553	5 473 864	12 153 549	9 306 269	1 188 070
		Grass/Agr	**181 637**	**1 808 770**	**3 556 739**	**2 115 365**	**866 806**	**-7 453 349**
		Unknown	*3 027 962*		*3 778 267*	*6 011 730*	*5 773 293*	*21 153 263*
	Ireland	Cropland						99 458
	Ukraine	*Unknown*						*1 707 543*
	UK	Cropland	373 520		95 347			104 039
		Unknown	*342 258*	*1 561 909*	*748 217*	*2 170 419*	*1 559 858*	*3 242 202*
	US	Cropland					498 998	647 855
		Unknown	*1 922 219*	*450 768*		*1 889 025*		
	Unknown	Cropland		*1 407 878*		*519 267*		*3 628 229*
		Unknown	*891 047*	*3 539 046*	*4 567 985*	*14 016 672*	*3 972 656*	*1 565 544*
Palm	Indonesia	Cropland		2 294 098	787 474	2 300 790	4 287 044	4 002 304
		Grass/Agr				**361 133**		**-361 133**
		Unknown	*541 197*	*412 591*	*782 664*	*1 279 469*	*1 251 987*	*361 133*
	Malaysia	Cropland	175 048	1 640 800	2 336 866	3 782 464	4 251 925	3 779 890
		Unknown		*400 869*	*1 446 481*	*1 494 861*	*2 305 034*	*1 711 018*
	US	*Unknown*				*123 567*	*-123 567*	
	Unknown	Cropland			*152 250*		*1 497*	*1 381*
		Unknown	*5 586 756*	*3 460 551*	*5 766 434*	*8 285 406*	*2 688 822*	*1 066 808*
Soy	Argentina	Cropland		42 693	8 904 486	2 890 646	7 549 985	3 782 232
		Unknown				*281 653*	*3 708 208*	*2 189 536*
	Brazil	Cropland			205 954	584	59 433	
		Grass/Agr				**160 158**		**-160 158**
		Unknown	*1 278 486*	*197 062*	*1 621 939*	*2 440 237*		*182 408*
	US	Cropland	13 939 515	22 143 566	19 552 722	17 201 474	23 162 511	26 311 989
		Unknown	*2 331 900*	*6 058 137*	*4 196 570*	*963 546*	*1 760 787*	*9 311 399*
	Unknown	Cropland					*19 018*	*17 533*
		Unknown	*15 816 070*	*8 585 798*	*3 803 801*	*5 121 431*	*8 416 098*	*2 020 391*
Sunflower	Ukraine	Cropland			142 794	715 545	902 595	222 365
		Unknown						*5 969*
Tallow	Denmark	By-prod.			1 396 806	1 306 275		860 993
	Germany	By-prod.		446 789	100 321			
	Ireland	By-prod.					69 184	332 794
	UK	By-prod.	354 983	2 005 796	160 253	-1	619 316	841 298
	US	By-prod.	4 015 770	5 922 376	11 264 002	12 089 419	9 389 153	11 585 991
	Unknown	By-prod.	*3 514 544*	*3 277 313*	*314 791*	*-2 683 496*	*138 864*	*18 876*
		Unknown					*1 806*	*-1 806*
Used Cooking Oil	Germany	By-prod.			61 904			91 562
	Ireland	By-prod.					103 776	380 334
	Neth.	By-prod.			1 651			
	UK	By-prod.	2 806 962	4 447 442	4 116 130	3 783 910	2 120 046	3 403 403
	Unknown	By-prod.	*182 309*	*172 574*	*101 949*		*154 098*	*72 706*
Unknown	*Unknown*	*Unknown*	*11 612 316*	*9 007 496*	*7 390 141*	*-10 109 771*	*2 316 986*	*1 046 227*

Table 39: Agroethanol and biogas monthly consumption during the first semester of the RTFO

Feed-stock	Country of origin	Previous land-use	Apr-May 2008	May-June 2008	June-July 2008	July-Aug 2008	Aug-Sep 2008	Sep-Oct 2008
Cheese	Ireland	By-prod.			960			
Molasses	*Unknown*	By-prod.	*96 025*	*162 688*		*938 910*	*83 723*	
Sugar beet	UK	Cropland	3 262 191	5 405 522	3 402 456	-1 403 325	2 730 361	3 403 306
Sugar cane	Brazil	Cropland			2 498 704	16 532 829	12 864 169	3 571 515
		Unknown	*8 808 922*	*20 652 550*	*5 787 162*	*2 005 137*	*1 968 126*	*10 515 220*
	Pakistan	*Unknown*			*1 046 364*			
Unknown	*Unknown*	*Unknown*	*43 991*	*417 599*	*56 620*	*-273 915*	*54 955*	*109 265*
Biogas from MSW & manure	UK	By-prod.					24 000	72 540
Total mean			**86 983 639**	**122 708 284**	**110 546 789**	**112 609 096**	**117 487 702**	**116 838 033**

Table 40: Agrodiesel monthly consumption during the second semester of the RTFO

Feed-stock	Country of origin	Previous land-use	Oct-Nov 2008	Nov-Dec 2008	Dec 2008-Jan 2009	Jan-Feb 2009	Feb-Mar 2009	Mar-Apr 2009
Oilseed rape	Belgium	Cropland			2 469	31 184		
		Unknown				*87 230*	*21 929*	
	Canada	Cropland		96 865	1 489 287	847 210	275 606	2 362 545
	France	Cropland						1 813 754
		Unknown	*883 475*	*2 671 226*	*1 018 876*	*1 300 241*		*21 780*
	Germany	Cropland	10 076 751	6 334 166	10 465 013	5 128 464	4 533 392	3 009 647
		Grass/Agr		**-262 691**				
		Unknown	*6 898 292*	*7 867 203*	*8 580 973*	*2 791 192*	*-17 731 074*	*2 367*
	Sweden	Cropland				491 495	507 568	
	Ukraine	*Unknown*	*1 108 914*		*887 456*	*820 501*	*-1*	*2 691 113*
	UK	Cropland	1 646 792	76 600	334 998	7 729 897	2 145 584	338 433
		Unknown	*3 563 553*					*59 267*
	US	Cropland	376 876	7 042 695				2 912 887
		Unknown		*329 692*				
	Unknown	Cropland		*4 051 995*				*129 075*
		Unknown	*5 050 477*	*4 925 593*	*3 823 200*	*5 434 503*	*23 482 009*	*11 540 876*
Palm	Indonesia	Cropland	1 041 556	1 671 550	2 683 613	613 662	147 451	1 431 857
		Unknown	*1 037 690*	*1 567 165*	*-1 321 785*	*65 806*		*44 508*
	Malaysia	Cropland	7 155 262	3 877 530	4 309 475	7 556 508	4 057 713	7 240 217
		Unknown	*905 649*	*1 635 170*	*1 807 031*	*1 657 509*	*197 828*	*56 164*
	US	*Unknown*			*767 026*	*-767 026*		
	Unknown	Cropland		*-155 128*				
		Unknown	*797 756*	*810 827*	*347 143*	*2 246 389*		*988 519*
Soy	Argentina	Cropland	2 307 221	5 505 877	7 128 963	*7 411 358*	7 805 721	6 994 047
		Unknown	*5 609 038*	*1 537 039*	*1 264 271*	*391 852*	*17 987*	*3 038 484*
	Brazil	Cropland					12 422	68 129
		Unknown	*69 607*	*30 326*	*117 338*			*36 458*
	US	Cropland	17 000 197	18 903 938	18 230 521	*22 279 603*	9 046 470	24 074 472
		Unknown	*8 426 477*	*5 511 246*	*-1 215 519*	*2 878 066*	*1 442 615*	*3 820 861*
	Unknown	Cropland	*1 231 966*	*-1 268 517*			*55 876*	*1 641*
		Unknown	*7 772 532*	*3 483 142*	*4 760 774*	*4 889 069*	*4 914 063*	*-1 885 041*
Sunflower	Sweden	*Unknown*						*24 148*
	Ukraine	Cropland	14 029	111 668	57 659			53 723
		Unknown						*-5 969*
Tallow	Belgium	By-prod.					25 906	
	Denmark	By-prod.		184 104			7 451	
	France	By-prod.					89 944	
	Germany	By-prod.		1 769			148 975	
	Neth.	By-prod.					67 095	
	UK	By-prod.	47 927	106 878			31 484	1 020 222
	US	By-prod.	4 268 072	6 312 975	7 015 653	*6 665 456*	7 532 421	11 160 255
	Unknown	By-prod.	*277 185*		*1 520 266*		*11 233*	
Used Cooking Oil	Germany	By-prod.					210 940	
	Ireland	By-prod.				*28 991*	24 475	311 581
	Neth.	By-prod.	26 437	38 731				
	Switz.	By-prod.						
	UK	By-prod.	1 481 981	2 981 436	2 006 134	*1 002 191*	1 038 317	4 510 788
	Unknown	By-prod.		*226 100*			*1 100 205*	
Unknown	*Unknown*	*Unknown*	*9 740 972*	*-6 375 959*	*11 889 087*	*3 798 520*	*1 398 264*	*-25 962 689*

Table 41: Agroethanol and biogas monthly consumption during the second semester of the RTFO

Feed-stock	Country of origin	Previous land-use	Oct-Nov 2008	Nov-Dec 2008	Dec 2008-Jan 2009	Jan-Feb 2009	Feb-Mar 2009	Mar-Apr 2009
Molasses	Malawi	By-prod.	1 281 346		67 953			
	Unknown	By-prod.	*-1 281 346*					
Sugar beet	UK	Cropland	3 698 445	2 078 573	4 938 634	*4 978 079*	1 494 327	3 318 009
Sugar cane	Brazil	Cropland	4 720 306	4 229 393	5 631	*1 685 434*	12 949 883	42 726 557
		Unknown	*10 662 860*	*11 692 018*	*10 982 362*	*8 014 174*	*3 044 061*	*-16 753 387*
	Unknown	*Unknown*						*49 522*
Sulphite	Sweden	By-prod.		79 800	79 798	*53 200*	53 200	521 301
Unknown	Pakistan	*Unknown*						*1 098 757*
	Unknown	*Unknown*	*53 200*		*50*			*78 655*
Biogas from MSW & manure	UK	By-prod.	52 000		142 480			124 680
Total mean			**118 003 495**	**97 910 995**	**104 186 830**	**100 110 758**	**70 161 340**	**93 068 213**

Table 42: Agrodiesel monthly consumption during the third semester of the RTFO

Feed-stock	Country of origin	Previous land-use	Apr-May 2009	May-June 2009	June-July 2009	July-Aug 2009	Aug-Sep 2009	Sep-Oct 2009
Oilseed rape	Belgium	Cropland			3 482 281			
		Unknown					4 113	514
	Canada	Cropland	479 712	140 805	1 132 358			
	France	Cropland	1 130 393	10 655	44 924	1 415 306	2 125 935	1 438 840
	Germany	Cropland	8 616 728	6 250 823	6 938 878	6 524 666	6 521 875	8 388 972
		Unknown	615 769				802 325	3 671
	Neth.	Cropland				1 304 862		806 117
		Unknown					16 449	2 057
	Poland	Unknown						524
	Sweden	Cropland			103 773	650 773	1 068 812	
	UK	Cropland	2 081 915	1 118 205	1 225 906	726 569	695 937	1 817 195
		Unknown	486 092	533 377	2 199 032	983 644		-633 881
	US	Cropland	183 569	1 909 196	1 327 051		176 439	
	Unknown	Cropland				15 769	-15 769	
		Unknown	3 690 651	2 575 046	2 387 234	1 087 800	1 790 888	2 944 082
Palm	Indonesia	Cropland	320 603	847 148	4 564 901	3 496 008	1 371 945	1 201 011
		Unknown	79 304		612 079	2 359 206	2 682 100	386 682
	Malaysia	Cropland	4 588 320	3 860 561	4 408 499	4 362 518	6 569 985	4 286 611
		Unknown	2 674 421	3 062 029	20 025	272 794		1 453 993
	Unknown	Unknown	147 025	831 899	610 718	1 365 891	514 401	2 901 243
Soy	Argentina	Cropland	5 452 712	5 770 179	13 311 555	7 213 208	13 504 613	11 464 693
		Unknown	3 956 996	9 960 827	10 920 801	17 358 392	21 019 682	16 473 487
	Belgium	Unknown	702 782	2 529 582	-3 232 364			
	Brazil	Cropland	197 796	17 688			99 832	
		Unknown			543 404			20 246
	UK	Cropland	19 078					
	US	Cropland	17 261 647	8 237 558	9 169 607	7 395 733	10 003 591	6 683 271
		Unknown	1 874 586	3 726 737		19 198		
	Unknown	Unknown	2 946 440	-965 420	1 766 767	4 364 184	-2 850 009	1 938 913
Sunflower	Ukraine	Cropland	140 605	11 934	49 916			

Table 43: Agrodiesel monthly consumption during the third semester of the RTFO (following)

Feed-stock	Country of origin	Previous land-use	Apr-May 2009	May-June 2009	June-July 2009	July-Aug 2009	Aug-Sep 2009	Sep-Oct 2009
Tallow	Belgium	By-prod.				31 522		
	Canada	By-prod.	500 000	116 514				
	Denmark	By-prod.		1 956 388	4 908 404	1 744 571	4 759 044	3 025 281
	France	By-prod.				20 937	134 277	1 096 535
	Germany	By-prod.	359 152	2 572 603	531 406	1 352 229	337 539	2 917 266
	Ireland	By-prod.			1 150 051	1 930 214	685 142	112 337
	Italy	By-prod.						37 089
	Neth.	By-prod.				178 079	28 681	9 272
	Poland	By-prod.						921 771
	Switz.	By-prod.						343
	UK	By-prod.	2 962 076	3 025 097	5 617 140	3 864 383	3 362 368	1 120 581
	US	By-prod.	11 836 904	9 230 000	8 449 695	10 322 371	8 034 707	5 005 482
	Unknown	By-prod.	*286 432*	*2 724 203*	*790 095*	*2 528 901*	*1 757 686*	*1 346 197*
Used Cooking Oil	Belgium	By-prod.			55 605			
	France	By-prod.			122 331			
	Germany	By-prod.	70 463	282 805	966 963	98 123	133 898	765 477
	Ireland	By-prod.				8 700		26 450
	Neth.	By-prod.				132 970		
	UK	By-prod.	3 872 970	2 357 709	3 002 955	2 035 222	3 279 952	2 473 780
	Unknown	By-prod.		*1 355 341*	*168 212*		*-126 372*	*64 345*
Unknown	UK	By-prod.						*12 961*
	Unknown	*Unknown*	*12 002 148*	*12 757 723*	*10 839 241*	*9 805 809*	*12 310 491*	*13 645 129*

Table 44: Agroethanol and biogas monthly consumption during the third semester of the RTFO

Feed-stock	Country of origin	Previous land-use	Apr-May 2009	May-June 2009	June-July 2009	July-Aug 2009	Aug-Sep 2009	Sep-Oct 2009
Sugar Beet	UK	Cropland	2 226 426	2 573 329	2 722 745	5 760 855	4 881 827	5 282 665
		Unknown						
Sugar cane	Brazil	By-prod.		1 430 190			-1 430 190	
		Cropland	11 016 329	13 638 382	12 822 605	10 487 605	23 666 857	28 561 715
		Unknown	*102 207*	*308 013*	*8 247 681*	*7 439 594*	*-2 850 721*	*-3 991 619*
Sulphite	Sweden	By-prod.	53 210	80 343	53 202	79 412		53 145
Unknown	Pakistan	*Unknown*	*434 409*					
	Unknown	*Unknown*	*351*			*1 259 663*	*3 416 364*	*3 305 308*
Biogas from MSW & manure	UK	By-prod.			36 500			20 000
Total mean			**103 370 221**	**104 837 469**	**122 072 176**	**119 997 681**	**128 484 694**	**127 389 751**

Table 45: Agrodiesel monthly consumption during the fourth semester of the RTFO

Feed-stock	Country of origin	Previous land-use	Oct-Nov 2009	Nov-Dec 2009	Dec 2009-Jan 2010	Jan-Feb 2010	Feb-Mar 2010	Mar-Apr 2010
Corn oil	US	By-prod.				9 698	83 720	
Oilseed rape	Belgium	Cropland	8 843					97 335
		Unknown	6 887	8 242	733	543	6	1
	Denmark	Cropland			789 782	908 276	239 017	404 328
		Unknown			192 775	312 359	3 783	28 226
	France	Cropland	4 309 019	1 901 735	941 969	1 316 006	2 074 386	4 469 273
		Unknown	2 144 558	506 259	1 822 475	3 993 442	1 581 155	2 543 135
	Germany	Cropland	2 794 720	9 262 523	8 632 353	10 035 197	7 944 255	6 730 875
		Unknown	500 406	687 489	3 684 943	2 370 507	4 173 284	2 278 006
	Hungary	Cropland		22 883				
	Latvia	Cropland			442 545	1 381 015		
		Unknown	25 126	492 899	3 782			144 768
	Neth.	Cropland	256 377				2 064 677	
		Unknown	27 557	32 633	2 937	2 174	23	386 560
	Poland	By-prod.	228 828	-228 828				
		Cropland		228 828				
		Unknown	611 575	558	272 639		81 650	25 196
	Sweden	Cropland		56 601			1 008	1 063
	Ukraine	Unknown	261 573	1 518 777	349 384	1 800 048	1 637 058	3 533 035
	UK	Cropland	980 599	1 253 930	3 401 087	417 823	1 820 505	3 065 208
		Unknown	196 310	464 171	89 862			1 850
	US	Cropland	3 193 567					
		Unknown				762 115	788 574	639 927
	Unknown	Cropland	22 883	-22 883				929 678
		Unknown	5 736 505	2 448 064	1 573 590	508 397	1 142 858	1 609 286
Palm	France	Cropland						354 527
	Indonesia	Cropland	2 387 689	137 696	92 452	91 335		3 035 934
		Unknown	1 644 716	650 169	105 542	-183 710	12 883	-106 479
	Malaysia	By-prod.		210 111	-210 111			
		Cropland	5 370 522	3 483 369	1 056 559	2 270 861	1 160 616	9 144 102
		Unknown	4 114 082	824 252	1 581 585	1 510 663	1 259 630	1 663 803
	Unknown	Cropland						1 155 763
		Unknown	3 019 679	1 565 023	46 740	-1 073 754	2	-3 906
Soy	Argentina	By-prod.	1 144 160	-1 144 160				
		Cropland	21 278 164	7 343 011	7 373 471	16 385 454	19 157 474	29 726 819
		Unknown	26 051 014	13 415 963	8 771 451	16 728 998	4 880 391	7 745 016
	Brazil	Unknown	43 857					
	UK	Cropland	-19 078					
	US	Cropland	9 617 549	6 556 939	5 462 454	-405 772	2 671 390	17 714 810
		Unknown	715 240	1 560 056	1 346 138	5 944 691	4 910 203	-6 265 662
	Unknown	Unknown	8 818 194	3 791 803	3 156 575	1 135 879	-48 635	-439 202

Table 46: Agrodiesel monthly consumption during the fourth semester of the RTFO (following)

Feed-stock	Country of origin	Previous land-use	Oct-Nov 2009	Nov-Dec 2009	Dec 2009-Jan 2010	Jan-Feb 2010	Feb-Mar 2010	Mar-Apr 2010
Tallow	Canada	By-prod.	4 411 131	3 028 399	2 481 423	3 248 278	107 379	240 245
	Denmark	By-prod.	973 838	130 719	832 974	2 189 408	1 821 370	4 518 779
	Finland	By-prod.				234 170		
	France	By-prod.	256 373	156 784	391 108	61 917	63 366	93 140
		Cropland	244 450	96 528	-340 978			
	Germany	By-prod.	1 543 509	978 130	504 927	715 178	1 517 563	1 431 153
		Cropland	50 576	20 392	-70 968			
	Ireland	By-prod.	225 304	553 029	352 816			
	Italy	By-prod.	176 924	66 817	9 670		167 155	
	Neth.	By-prod.	22 566	16 537	2 418		515 200	350 011
	Poland	By-prod.	549 388	99 701	53 049	49 078	46 846	84 030
	Switz.	By-prod.	3 607	125	563 089			154 816
	UK	By-prod.	1 744 699	2 698 823	2 589 156	2 056 502	2 985 388	7 398 816
	US	By-prod.	2 470 808	4 755 974	2 343 068	2 265 028	985 666	127 721
	Unknown	By-prod.	*1 860 703*	*83 602*	*629 765*	*369 287*	*-161 055*	*927 234*
Used Cooking Oil	Austria	By-prod.						305 108
	Belgium	By-prod.						623 943
	Chile	By-prod.						217 142
	France	By-prod.		27 000		111 359		533 505
	Germany	By-prod.	118 470	251 156	52 746	62 247	212 099	64 363
	Ireland	By-prod.	27 316	20 620	25 579	55 967	108 178	67 648
	Neth.	By-prod.		62 042			600 000	1 285 115
	Switz.	By-prod.						305 107
	UK	By-prod.	2 455 920	2 550 846	1 508 148	792 227	4 958 338	5 050 431
		Unknown						9 753
	Unknown	By-prod.	*354 670*	*2 077 683*	*320 510*	*423 819*	*360 949*	*407 456*
Unknown	UK	By-prod.		*-12 961*				
	Unknown	*Unknown*	*-33 960 306*	*11 664 142*	*14 958 711*	*9 574 971*	*15 016 647*	*4 939 991*

Table 47: Agroethanol and biogas monthly consumption during the fourth semester of the RTFO

Feed-stock	Country of origin	Previous land-use	Oct-Nov 2009	Nov-Dec 2009	Dec 2009-Jan 2010	Jan-Feb 2010	Feb-Mar 2010	Mar-Apr 2010
Barley	Spain	Cropland					99 914	
	Unknown	*Unknown*					*197 717*	
Cassava	Cambodia	*Unknown*						*58 621*
Corn	France	Cropland					5 338 211	2 916 977
		Unknown			*4 974 205*	*1 468 793*	*-1 839 663*	*302 184*
	Hungary	*Cropland*					275 556	
	Spain	*Cropland*					275 556	
Molasses	Brazil	By-prod.					1 326 773	989 562
	Costa Rica	Cropland						1 380 294
	Guatemala	By-prod.						961 857
	Nicaragua	Cropland						267 327
Sugar beet	Belgium	Cropland				645 231		
	France	Cropland		947 642	8 082 640	2 646 766		635 141
	UK	Cropland	4 801 268	5 430 193	4 740 309	6 192 356	6 789 262	11 139 046
		Unknown					*435 075*	
Sugar cane	Brazil	Cropland	24 566 443	42 551 016	13 241 908	11 665 882	56 829 580	26 376 892
		Unknown	*6 400 838*	*-5 248 462*	*14 341 121*	*17 465 255*	*-20 320 365*	*7 686 151*
Sulphite	Sweden	By-prod.	79 645	53 354	53 857	54 543	54 461	27 170
Triticale	Lithuania	*Unknown*					*207 392*	*284 120*
	Unknown	*Unknown*					*297 237*	
Wheat	Belgium	Cropland		263 127	832 863			
		Unknown					*1 931 837*	2 646 546
	France	Cropland	5 220 963	6 072 296	290 658	4 905 420	8 056 399	8 098 781
		Unknown					*253 794*	
	UK	Cropland						942 899
Unknown	Brazil	*Unknown*						157 707
	Unknown	*Unknown*	*1 457 447*	*1 018 316*	*2 974 716*	*5 733 995*	*-4 330 928*	*-1 224 139*
Biogas from MSW & manure	UK	By-prod.			71 400			67 897
Total mean			**131 547 671**	**137 441 683**	**127 794 600**	**139 209 922**	**142 822 810**	**183 463 815**

Appendix B: List of persons contacted for the French case study

Table 48: List of persons contacted for the French case study

First name	Surname	Organisation or function
Anthony	Benoist	PhD student at Mines ParisTech
Henri	Boyé	French Ministry of Ecology
Karine	Brûlé	French Ministry of Agriculture
Marjorie	Buliard	French Customs
Xavier	Chavanne	Université Diderot Paris 7
Yves	Cochet	Green Member of the French Parliament
Jérôme	Frignet	Greenpeace France
Marie-Cécile	Hénard	Agricultural economist, US Embassy in Paris
Paul	Hodson	European Commission, DG TREN
Elise	Levaillant	DGEC, Ministry of Ecology
Pierre	Perbos	*Réseau Action Climat - France*
Emilie	Pons	PhD student at Science-Po Paris
Bruno	Rebelle	Consultant – Synergence
Patrick	Sadones	*Environnement et Développement en Normandie*
Jean-Marc	Salmon	Consultant
Anne	Sirop	Proléa
Lionel	Vilain	*France Nature Environnement*
Antoine	Waechter	Leader of the *Mouvement Ecologiste Indépendant*

Appendix C: French fuel consumption data used for agrofuel blending calculations

The following tables contain data of French fuel consumption that were used for the calculations of agrofuel blending by energy content in chapter 5.

All figures from 2004 and 2008 come from selected data of the French reports to the European Commission, apart from the consumption of 'total diesel' for 2008 that comes from UFIP data because of a too big difference with data mentioned in the French report to the EC.

As to 2009 data, they all come from an Excel spreadsheet from the French customs sent to the DGEC of the French Ministry of Sustainable Development and transmitted by Elise Levaillant.

Table 49: Data of French consumption of petrol-like fuels used for agroethanol blending calculations by energy content

	Agro-ETBE	Unit		Direct ethanol	Unit		'Total petrol'	Unit
2004	161,148	t		704	t		15,463,326	m^3
2005	228,845	t		3,374	t		10,969,668	t
2006	293,424	t		94,000	t		13,638,658	m^3
2007	767,726	t		44,000	t		9,849,000	t
2008	432,097	t		375,000	t		12,000,000	m^3
2009	993,931	m^3		334,381	m^3		11,600,683	m^3

Table 50: Data of French consumption of diesel-like fuels used for agrodiesel blending calculations by energy content

	Agrodiesel	Unit		'Total diesel'	Unit
2004	323,720	t		36,404,500	m^3
2005	368,487	t		31,048,330	t
2006	631,000	t		37,109,511	m^3
2007	1,300,000	t		31,253,000	t
2008	2,100,000	t		32,022,265	m^3
2009	2,615,757	m^3		38,348,073	t

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