Energy Charter Secretariat

DRIVING WITHOUT PETROLEUM?

May 2007

A Comparative Guide to Biofuels, Gas-to-Liquids and Coal-to-Liquids as Fuels for Transportation

Prepared for

Energy Charter Secretariat

Brussels, Belgium

By

OK-SOLUTIONS, INC.

710 Asp Ave., Suite 309, Norman OK 73069

(www.ok-solutions.org)

Miguel Bagajewicz[(§)], Daniel Sujo, David Martinez and Mariano Savelski

Boyko Nitzov (Editor)

(§) Corresponding author

The text of this report reflects information available as of mid-February 2007

Boulevard de la Woluwe, 56
B-1200 Brussels, Belgium

ISBN: 978-90-5948-050-6 (PDF)

Dépôt Légal (Belgium): D/2007/7850/4

FOREWORD

A key principle of the Energy Charter is the pursuit of sustainable development by taking into account the international agreements concerning the environment to which the Contracting Parties adhere, and the minimisation in an efficient manner of the environmental impact of all operations within the energy cycle. In particular, the Charter promotes developing and using renewable energy sources and cleaner fuels, and employing technologies and technological means that reduce pollution. The Contracting Parties have agreed accordingly to promote the transparent assessment at an early stage and prior to decision, and subsequent monitoring, of environmental impacts of environmentally significant investment projects.

For these reasons, and also in response to the recent great interest from all quarters in the potential of biofuels as an alternative to petroleum-based fuels in the transportation sector, the Energy Charter's Investment Group undertook the development of concise guidelines to non-petroleum fuels and technologies (biofuels, coal-to-liquids, and gas-to-liquids). Following discussions at the Investment Group's meeting in October 2005, in the framework of a broader dialogue concerning the reduction of risks in the energy sector, the Energy Charter Secretariat presented a paper on risks and other investment issues related to the development of alternative (non-petroleum) liquid fuels, particularly liquid biofuels, to the Investment Group Meeting in May 2006. Delegations recommended the use of outside expertise in order to develop a broader-ranging overview of non-petroleum based liquid fuels for the next meeting of the Group in October 2006, including a brief review of technologies, costs and benefits of all alternative transportation fuels, and not only biofuels.

This paper contains the results of such a review, prepared with the help of external consultants. It was discussed, and – with relevant changes included – recommended for public distribution by the Investment Group of the Energy Charter. The document shows the 'big picture' of producing and using non-petroleum transportation liquid fuels (bioethanol, biodiesel, and synthetic fuels) in key markets. Both 'first generation' biofuels (for which technologies are already commercially deployed) and 'second generation' fuels (for which research and development is underway, but without, as yet, commercial deployment) are considered. The guidelines are a desktop analysis and intend to give the best possible assessment of non-petroleum liquid fuels and provide useful conclusions and ready reference to the non-technical person.

The guidelines point out that biofuels are not a magic bullet that can solve all problems related to the supply and use of petroleum-based liquid fuels. Just like any other manufactured resource, they have their costs and benefits, both internal and external to the specific market, and should be assessed in rigorous terms in each instance. One important conclusion is that a good assessment of the feasibility of liquid non-petroleum transportation fuels on a continuous basis needs a robust model that accounts for the specific location, area and market and is capable of producing new results when parameters (inputs, output, prices, demand, etc.) change. Finally, the synergistic effect of various technologies, inter-regional and international sharing of resources to address energy production, surpluses and deficits, should be taken into account when making decisions about biofuels.

While the study contains specific policy conclusions, it is published under my authority as Secretary General and is without prejudice to the positions of Contracting Parties or to their rights or obligations under the Energy Charter Treaty.

André Mernier
Secretary General

30 April 2007

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Summary

Mandate and Scope

Following discussions at the Investment Group's meeting in October 2005 (IN-45) in the framework of the Risk Reduction Dialogue, the Energy Charter Secretariat presented a paper on risks and other investment issues related to the development of alternative (non-petroleum) liquid fuels, particularly liquid biofuels, to the Investment Group Meeting in May 2006 (IN-50). Delegations recommended the use of outside expertise in order to develop a broader-ranging overview of non-petroleum based liquid fuels for the next meeting of the Group in October 2006, including a brief review of technologies, costs and benefits of alternative transportation fuels, and not only biofuels. This paper contains the results of such a review, prepared with the help of consultants. It was reviewed, discussed, and – with relevant changes included – recommended for distribution to the public by the Investment Group of the Energy Charter.

The document shows the "big picture" of producing and using non-petroleum transportation liquid fuels (bioethanol, biodiesel, and synthetic fuels) in key markets. Both "first generation" biofuels (for which technologies are already commercially deployed) and "second generation" fuels (for which research and development is underway, but no commercial deployment is there yet) are considered.[1]

Two currently existing technically viable options (biomethanol and biogas) are not considered in detail, for the following reasons:

- Methanol for use in non-stationary applications is not a common practice since it is a by-product of biomass fermentation, is toxic, has less energy than ethanol and biodiesel, and is, in addition, used as feedstock for the production of biodiesel.
- The direct use of biogas is more expensive (due to storage and transport problems) than transforming it to liquid synthetic fuel.

In addition, the report briefly mentions research and incentive regulatory efforts regarding second generation fuels (biogas-to-liquids – BTL, "MixAlco", etc.). The paper also describes briefly (in Annex I) efforts about the use of fuel cells and the "hydrogen economy", which would compete with or complement biofuels and synthetic fuels.

The task of comparing these diverse fuels presents considerable difficulties because of the difference in raw materials and fuel delivery options, and is especially made hard by the fact that there is disagreement over some important and crucial technical information.

This study is a desktop analysis and intends to give the best possible assessment of non-petroleum liquid fuels and provide useful conclusions and ready reference to the non-technical person. Some of the most relevant points are listed below.

---

[1] "First generation" liquid biofuels include sugar and grain ethanol, methanol, biodiesel from vegetation and seeds. "Second generation" liquid biofuels include cellulose-based ethanol, biomass-to-liquids (BTL) and certain other fuels (see text below for detail).

Main Conclusions

Economic Conclusions

- Currently deployed biofuel technologies are generally grain and sugar-based (for ethanol) and seed oil-based (for biodiesel). The technologies are efficient within a certain support framework, including government taxation and subsidies policies. However, the availability of feedstock is a major constraint. Bioethanol, biomethanol, biogas, and synfuels have received larger attention than other existing options because (a) they are compatible with current vehicle engines, fuels, and distribution infrastructure that require little or no modification; (b) low-percentage bioethanol-gasoline and biodiesel-diesel blends are already sold in many service stations worldwide at varying admixture ratios and either meet no customer resistance or are welcome. However, alternative fuels educational campaigns are needed.
- Enabling the use of cellulose-rich waste and cellulose crops grown in areas that are not otherwise good for cultivation could enhance the potential for biofuels to the magnitude of one-third of worldwide gasoline demand. Therefore, support of research and development (R&D) in cellulose-based ethanol seems well warranted where this could lead to cost-competitive solutions.
- Synthetic fuels from natural gas and coal (gas-to-liquids – GTL, and coal-to-liquids – CTL) are efficient with current technologies and at costs of competing fuels above $25 per barrel. However, GTL may face feedstock constraints in the long run (beyond 20-30 years) similar to the much debated supply constraint – if any – for petroleum. Finally, CTL may produce excessive greenhouse gas emissions.
- Both biofuels and synfuels costs trend downwards and have decreased since inception due to many technological advances and better agricultural practice. However, prices have fluctuated due to policy changes, weather conditions, and feedstock demand for other purposes. In addition, while the competitive advantage of biofuels over petroleum-based ones rests on fiscal aids and environmental benefits (they are claimed to be renewable and environment-friendly), synfuels from natural gas and coal are able to be price-competitive where coal and gas is abundant. The competitive advantage will increase with higher oil prices for both.
- Today’s typical biofuels from non-cellulose crops (sugar, grains, oil seeds) require subsidies in various parts of the supply chain to be able to compete with current petroleum-based fuels. These subsidies come in various forms, such as cash injections at different production phases, tax reductions, forgiven charges, etc. For instance, in the US ethanol production subsidy benefits are almost $0.20 per equivalent litre of gasoline and $0.29 for biodiesel. In order to eliminate such subsidies, the costs of these biofuels would need to be reduced by optimising the processes, increasing crop yields, and allocating land areas to reasonably sized plants to tap into economies of scale. However, should the price of oil stay above $25 per barrel, subsidies may not be necessary anymore in the Brazilian case, especially if the general cost trend for biofuels continues to go down as observed.
- A few companies have published their return on investment (ROI) in biofuels. It ranges for bioethanol between 15 and 20% (with subsidies and tax breaks accounted for). In the case of GTL and CTL, there are no published data about the corresponding ROI.

Independent assessment of these benefits could not be made using the existing information at the time when these guidelines were prepared.

- A definitive cost and ROI analysis could not be made for the purpose of these guidelines because of many uncertainties of the data presented in the literature. Also, it must be underlined that the analysis of subsidy effects varies from crop to crop, from fuel to fuel, and from country to country. Therefore, investment planning models are needed, which should incorporate detailed process and associated supply chain data, anticipating an increasing role of the private sector, as well as possible government policies (taxation, subsidies, etc.).
- Biofuels could be an important source of employment and economic income diversification of the energy sector. Indeed, biofuels may be produced in a way that would contribute to decreasing concentration in the industry.

Environmental Conclusions

- Biofuels may reduce total carbon dioxide emissions by an average of 5.2% [based on 1990 greenhouse gases (GHG) levels] by 2010-2012 and thus be environment-friendly if and only if certain agricultural and refining practices are followed. In addition, the associated use of fertilisers and pesticides has negative environmental impacts, which should receive especial attention from policy makers.
- Although natural gas and coal from remote sources can be transformed into a clean-to-burn and cheap-to-transport liquid synthetic fuels (synfuels), these fuels have two drawbacks: CO_2 emissions generated in the overall CTL process exceed by 25% those observed in the manufacturing of petroleum-based fuels, whereas for liquids made from natural gas emissions are approximately the same as for petroleum-based fuels. However, carbon dioxide sequestration techniques are improving, although they add a cost. Despite these facts, synfuels can curb demand for petroleum-based fuels.

Technical Conclusions

- Feedstock availability and production technology are of critical importance. Sugar cane is the most efficient crop to produce ethanol, but it is very difficult to grow in most of the industrialised countries because of climate constraints. For this reason, sugar beet in Europe and corn in the United States have been supported as bioethanol feedstock, even though the associated cost is higher than that of sugar cane. Australia can grow sugar cane and recently has developed a genetically engineered sugar cane to ease processing of its cellulose material, thus increasing the ethanol yield and reducing energy inputs and costs.
- For biodiesel, rape and sunflower seeds have been chosen as feedstock in Europe and soybean in the United States. However, it was found that palm oil biodiesel is the cheapest and also has the best quality.
- Good practices for biofuels production at every production step are needed, but are yet to be established. To date, no life cycle analysis (LCA) study has compared different pathways of biofuels from “seed to wheels” in detail, so that the best option for reducing environmental impact and enhancing biofuels production benefits could be chosen. This also is applicable to synfuels from coal or gas.
- CTL production has very little environmental benefits in terms of abating GHG emissions; hence, new technologies are needed to bring the emissions down to

comparable values for petrofuels. However, CTL could satisfy long-term liquid fuels demand because of current proven coal reserves.

- ❖ The energy efficiency[2] of biofuels still needs to be properly assessed. Current data published in the open literature show conflicting results due to the different considerations applied when evaluating energy inputs. In a number of instances, the energy efficiency of biofuels in their production ("seed-to-plant gate") seems low or even negative; one should also consider energy use in fuel distribution and retailing.

Table 1 summarises comparatively the efficiency of the different fuels.

Table 1. Summary of different fuel efficiency aspects

	Relative Cost (not including taxes, €/l)	**Emissions of GHG (Kg_{CO2}/GJ_{OUT})**	**Energy Efficiency[f] GJ_O/GJ_I**	**Km_{travel}/m^2_{grown}**	**$Km_{travelled}/l$**	**Cost[o] (€/100Km travelled)**
E85	0.46 - 0.69	54.5[d]	1.25[g]	~0.35[j]	6.9[l]	6.7-10
B100	0.58 -0.72	22[d]	1.93[g]	~0.60[k]	~ 11[m]	5.3-6.5
GTL Diesel	0.10[a]	18.2-22.2[e]	1.93[h]	DNA	~ 11[m]	0.9
CTL Diesel	N/A	60.6[e]	N/A	DNA	~ 11[m]	N/A
BTL Diesel	0.25-0.35[b]	3.0[e]	N/A	DNA	~ 11[m]	2.3-3.2
(Petro)Diesel	0.57[c]	20.2[e]	0.843[i]	DNA	11.0[n]	5.2
Gasoline	0.50[c]	18.9	0.805[i]	DNA	8.5[m]	5.9

Note: Prices depicted in this table are for conceptualisation purposes only because of the strong variability of feedstock costs and the fact that the studies consulted do not make the same assumptions and were not performed at the same time.

N/A: Not available or not comparable due to out-of-basis

DNA: Does not apply

a: Dieselnet.com (2006) **b**: Ouwens & Faaij (2003) ; **c:** Herrera (2006); **d:** Institute of Transport Research et al. (2003)
e: ASFE (2006), Macedo et al. (2003) ; **f:** Energy output refers to the specific energy contained in final product-not the energy at the wheel; **g:** Based on Hill et al. (2006); **h:** Beer et al. (2006) ;**i:** Minnesota Department of Agriculture (2002) ; **j:** World Watch Institute (2006) using an average of yield of fermentable crops; **k:** With 544L/ha for soybean biodiesel, Hill et al. (2006);
l: DOE/EPA (2006); **m:** Iowa Department of Agriculture and Land Stewardship (2006) ; **n:** fueleconomy.gov (2006);
o: Based on relative cost before taxes from column 2 and $Km_{traveled}/l$ from column 6

Land Use Conclusions

- ❖ Land use is of critical importance. For example, in the US, if all corn and soybean cultivation areas were to be dedicated to grow biofuel crops only, corn ethanol could meet just 12% of gasoline demand and soybean only 6% of diesel demand. Aiming at simplicity, studies tend to generalise the feasibility of a crop by assuming the availability of large tracts of land or jumping over ecological barriers without taking into account local natural and meteorological constraints. Moreover, the economic and environmental impact of scattered agricultural spots is not taken into account in the models. In order to assess economic biofuel yields, environmental impacts, and optimise costs of certain crops used as feedstock, regional evaluations are needed to accurately assess costs and benefits.
- ❖ Biofuel agriculture may become an option only where abundant land is available; even in such locations it may compete with the conversion of agricultural land to nature, i.e., land dedicated to nature and used as a carbon sink.

---

[2] Defined as energy output/energy input in the production, distribution and retailing of biofuels ("seed-to-pump").

- Second-generation biofuels (SGB) are needed to reduce land use barriers currently faced by first-generation biofuels. Also, new SGB technologies would increase profitability by improving key aspects such as production yield and the energy balance of the entire process. Should SGB be demonstrated as a practical option, otherwise unused biomass sources like biological waste can curb land use problems. The MixAlco Process (transforming biomass waste into a mixture of higher molecular weight – higher energy content alcohols) has a promising future, but has received relatively less attention, and many improvements are still needed to achieve competitive production costs with higher yields.

Policy Conclusions

- Energy policies should favour (not necessarily in this order): (a) more efficient engines; (b) synfuels as a gateway for biogas-to-liquid; (c) research in second-generation biofuels (lignocellulose-to-fuel); (d) studies of regional agricultural conditions to optimise production and reduce the environmental impact; (e) establishing sustainable practices in the production of biofuels and synfuels; (f) establishing a legal framework that allows the free export/import of these fuels that are not distorted via customs duties and charges or quasi-measures, and simultaneously guarantees sustainable practices; (g) reaching all key stakeholders – investors, farmers, R&D entities, end-users, etc.
- Among the successful policies that have been implemented for the production and use of biofuels are: (a) blending mandates; (b) tax incentives; (c) government purchasing policies; (d) support for biofuel-compatible infrastructure and technologies; (e) RD&D (including crop research, conversion technology development, feedstock handling, etc.); (f) public education and outreach; (g) reduction of counterproductive subsidies; (h) investment risk reduction for next generation facilities; and (i) gradual reduction of support and intervention as market matures.

Recommended Method of Assessment

- One important conclusion is that (given the unreliable and conflicting data on costs, energy input-output, labour input and other factors that are not static) a good assessment of the feasibility of liquid non-petroleum transportation fuels on a continuous basis needs a robust model that accounts for the specific location, area and market and is capable of producing new results when parameters (inputs, output, prices, demand, etc.) change. Such a model should be also part of the models dealing with investment capacity planning under uncertainty that have been developed lately. Finally, the synergistic effect of various technologies, inter-regional and international sharing of resources to address energy production, surpluses and deficits, possibly taking advantage of each other’s by-products and with several end-products being implemented at a single site (“biorefineries”) should be taken into account in such planning models.

Recommended alternative fuels follow-up

- The MixAlco process requires special attention in the coming years. Land requirements and waste storage issues can be solved with this technology.
- Hydrogen and fuel cells are another possibility that could combine nuclear energy and bioproducts as sources of hydrogen.

Future Challenges

- Many technologies are proposed to be used synergistically, using by-products from each other and energy surplus in complexes of units referred to as “biorefineries”.
- Genetically modified crops have been of major interest. The development of these crops can be translated into higher biofuels yield per cultivated area, less investment, and economies of resources like water, pesticides, fungicides, etc.

* * *

Overall, one should not forget that biofuels are not a magic bullet that can solve all problems related to the supply and use of petroleum-based liquid fuels. Just like any other manufactured resource, they have their costs and benefits, both internal and external to the specific market, and should be assessed in rigorous terms in each instance.

1. Introduction

Concerns about the negative environmental impacts of the production and use of fossil fuels and the availability of petroleum supplies have spurred the search for alternative transportation fuels. This section introduces non-petroleum liquid transportation fuels.

What Are Non-petroleum Liquid Transportation Fuels?

These are liquid fuels produced from raw stock other than petroleum and intended for use in engines in transportation, such as spark ignition and diesel reciprocating engines and jet engines (gas turbines). Generally, non-petroleum liquid transportation fuels fall in two broad categories:

- **Fuels produced from non-fossil organic stock ("biofuels").** These fuels are divided in two branches. "First generation" biofuels (FGB) use stocks such as sugar, grains, oil-containing vegetation and seeds, animal fat, and waste cooking oil. "Second generation" biofuels (SGB) use non-directly fermentable biomass (*see* Table 2). Biogas (methane from manure and organic waste, gas made from biomass via thermal decomposition, i.e., pyrolysis), or cellulose-containing material (e.g., wood, straw, grass) are good examples of non-directly fermentable raw material. The commercial application of SGB is still under development (Sweeney, 2006).

Table 2. First and second generation biofuels processes

First Generation Biofuels			
Biofuel type	**Specific names**	**Biomass feedstock**	**Production process**
Bioethanol	Conventional bioethanol	Sugar beet, grains	Hydrolysis & fermentation
Vegetable oil	Pure plant oil	Oil crops	Cold pressing/extraction
Biodiesel	Biodiesel from energy crops: Rape seed methyl ester, Fatty acid methyl/ethyl ester (FAME/FAEE)	Oil crops	Cold pressing/extraction & transesterification
Biodiesel	Biodiesel from waste (FAME/FAEE)	Waste/cooking/frying oil/animal fat	Transesterification
Biogas	Upgraded biogas	Biomass	Digestion

Second Generation Biofuels			
Biofuel type	**Specific names**	**Biomass feedstock**	**Production process**
Bioethanol	Cellulosic bioethanol	Ligno-cellulose material	Hydrolysis & fermentation
Synthetic biofuels	Biomass-to-liquids (BTL): Fischer-Tropsch (FT) diesel Synthetic (bio)diesel Biomethanol Heavier (mixed) alcohols Biodimethylether (Bio-DME)	Ligno-cellulose material	Gasification & synthesis
Biodiesel	Hydro-treated biodiesel	Vegetable oils and animal fat	Hydro-treatment
Biogas	SNG (Synthetic Natural Gas)	Ligno-cellulose material	Gasification & synthesis

(Source: BRAC: Biofuels Research Advisory Council, 2006)

Among all biofuels, only biogas has to be further processed to arrive at liquid fuels, although various post-processing is needed for all biofuels to have them comply with safety requirements and emission standards, and adapt to the fuel delivery infrastructure and the engines. Since feedstock is renewable, biofuels are renewable, too, and potentially have other advantages such as low environmental impact. However, benign environmental impacts other than reducing combustion and greenhouse gases emissions at exhaust are unclear. Despite the possible benefits, detrimental environmental effects from the production and the use of biofuels need to be further clarified, i.e., acidification, erosion, land use changes, etc. (Blottnitz & Curran, 2006).

- **Fuels produced from fossil stock ("synthetic fuels" or "synfuels")**. Stock may be natural gas, oil shale, or coal. In this category, several chemical reaction steps are always required to arrive at liquid fuels from the gaseous or solid feedstock. This chemical synthesis is a rigidly controlled process and the resulting fuel is typically of very consistent quality. The process involves two steps: first, the production of synthesis gas (a mixture of carbon monoxide and hydrogen) from the feedstock; and second, the production of liquid hydrocarbons from the synthesis gas, usually performed using the *Fischer-Tropsch* (FT) process, developed by the two German researchers in 1923 (Table 3).

  The hydrocarbons are then split into fractions (gasoline, diesel, jet fuel, etc.) in a way similar to the distillation of crude oil. Apart from fuels, many other valuable products may be made from FT synthetic liquid hydrocarbons (e.g., high quality lubricants). Synthetic fuels can therefore be used without any restrictions as compared to petroleum-based fuels. In fact, synthetic fuels exceed petroleum-based fuels pollution preventing specifications and have lower pollutant emissions as well as other advantages *at the user end.* However, the manufacturing process is energy intensive and synfuels may render *larger overall* greenhouse emissions than petroleum-based fuels.

Table 3. Fischer-Tropsch process description for synfuels production

	Step I	**Step II**	**Step III**	**Step IV**
Step Description	Raw synthetic gas (syngas) production	H_2 to CO ratio adjustment to a value around two	CO_2 removal and desulphurisation when needed. H_2S removal may take place using hydrotreating after the fuel is synthesised	Fuel production
Reactions	Gas, biomass or coal conversion to a mixture of CO, CO_2 and H_2	-Reacting water with CO_2 to convert it to CO and hydrogen -Use of H_2 permeable membranes -Use combinations of technologies to adjust ratio	Absorb CO_2 and react H_2 S with metals	Creating long hydrocarbon chains from CO and hydrogen (by-product is water)
Processes	-Steam reforming -Partial oxidation reforming -Catalytic partial oxidation -Autothermal reforming -CO_2 reforming	-"Water gas" shift reactors - H_2 permeable membranes	Absorption in solvents (Amines, Selexol, etc.) Reacting H_2S with metals	Fischer Tropsch reactors and variants

(Source: Ondrey, 2004)

Accordingly, there are numerous combinations of feedstock and technologies ("pathways") for the production and use of various non-petroleum liquid fuels. Some of these liquids are very similar in composition and properties to petroleum-based fuels (gasoline, diesel and jet fuel) and can be used admixed in petroleum-based fuels in any proportion or neat without any change in the fuel delivery infrastructure and the engines. Others have composition and properties that are quite different from petroleum-based fuels, but may substitute them or be mixed with them, *provided certain conditions are met.*

The EU Directive for the promotion of the use of biofuels or other renewable fuels for transport states that “at least the products listed below shall be considered biofuels:

a) ‘bioethanol’: ethanol produced from biomass and/or the biodegradable fraction of waste, to be used as biofuel

b) ‘biodiesel’: a methyl-ester produced from vegetable or animal oil, of diesel quality, to be used as biofuel

c) ‘biogas’: a fuel gas produced from biomass and/or from the biodegradable fraction of waste, that can be purified to natural gas quality, to be used as biofuel, or wood gas

d) ‘biomethanol’: methanol produced from biomass, to be used as biofuel

e) ‘biodimethylether’: dimethylether produced from biomass, to be used as biofuel

f) ‘bio-ETBE (ethyl-tertio-butyl-ether)’: ETBE produced on the basis of bioethanol. The percentage by volume of bio-ETBE that is calculated as biofuel is 47%

g) ‘bio-MTBE (methyl-tertio-butyl-ether)’: a fuel produced on the basis of biomethanol. The percentage by volume of bio-MTBE that is calculated as biofuel is 36%

h) ‘synthetic biofuels’: synthetic hydrocarbons or mixtures of synthetic hydrocarbons, which have been produced from biomass

i) ‘biohydrogen’: hydrogen produced from biomass, and/or from the biodegradable fraction of waste, to be used as biofuel

j) ‘pure vegetable oil’: oil produced from oil plants through pressing, extraction or comparable procedures, crude or refined but chemically unmodified, when compatible with the type of engines involved and the corresponding emission requirements” (ECC, 2003a).

We summarise in Table 4 the fuels and pathways discussed in this report.

Table 4. Definitions of alternative fuels and pathways discussed in this report

Fuel	Description, production process	Raw Materials
Biomethanol	Methanol can be produced from wood by fermentation	Wood, ligno-cellulose material
Bioethanol	Via fermentation using a source of sugar	Corn, sugar cane and beets, sweet sorghum, wheat, black liquor (residue from pulp & paper industry), and manure
	Via cellulose degradation (e.g., with the help of enzymes) to break up the sugar complexes of lingo-cellulose, then via fermentation	Corn stover, switch grass, wood chips, or crop straws and cuttings
	Via anaerobic digestion of biomass (also producing biogas)	Organic waste from landfills
Biodiesel	Methyl-ester of diesel properties produced from vegetable or animal oil	Oil-containing seeds and vegetation (sunflower, rape, cotton, corn, olive, soy, algae), waste cooking oil (virtually any kind of oil, also animal fat, tallow)
Biogas*	Natural gas produced from biomass and/or the biodegradable fraction of waste	Biogas recovered from landfills, swamps or any organic material under decomposition
Gas-to-liquids (GTL)	Straight-chain hydrocarbons as waxy paraffin (gasoline-like and diesel-like) produced from coal, natural gas or biogas, or biomass, typically via Fischer-Tropsch synthesis	Natural gas or biogas
Biomass-to-liquids (BTL)		Biomass
Coal-to-liquids (CTL)		Coal

** Not liquid, but may be used as feedstock for BTL*

Summary: Best practices in identifying and assessing non-petroleum liquid transportation fuels involve the use of a classification by pathway (raw stock, technology, delivery system) and outcome (resulting fuel at engine) similar to the ones provided in this section. The assessment of the fuels should be on the basis of the entire cycle of their production and consumption, from obtaining the raw stock to the end use of the fuel (“well-to-wheels”, “seed-to-wheels”).

2. Main Facts about Biofuels, GTL and CTL

In this section, an overview is provided of the current status of production of biofuels, GTL and CTL worldwide and of the main issues discussed in conjunction with non-petroleum transportation liquid fuels.

2.1. Current Production of Biofuels, GTL, and CTL

A number of local conditions in different countries determine different outcomes for biofuels, GTL, and CTL. Production of biofuels is directly related to:

- Policies (farm, energy, environment)
- Availability of funds for research and building pilot and demonstration projects
- Research, Development and Design (RD&D) on biomass feedstock production, harvesting, storage, and transportation
- RD&D on biomass conversion technologies, transportation, and distribution
- Food demand and prices
- Meteorological conditions
- Crude oil prices.

Analogously, GTL and CTL are related to:

- Policies (exploitation, energy, environment)
- R&D on liquid fuels conversion technologies
- Crude oil prices.

Where and how are biofuels and synfuels produced and used? Table 5 depicts biofuels production for different countries highlighting the raw materials used. The type of crop used in every country depends on regional weather conditions, as well as its yield. Also, world production of biofuels for each country with the corresponding production volumes and raw material used is presented.

Brazil and the US are the major producers of ethanol. They use sugar cane and corn respectively; whereas in Europe sugar beets, wheat, potato, between many others, have been proposed, however production is very limited. On the other hand, Europe is the world leading producer of biodiesel, mainly from rape and sunflower seeds, but the US is also advancing. For example, Chevron has recently acquired 22% stake of Galveston Bay Biodiesel that is currently being built. The facility would be able to produce 75.7 million litres[3] per year of biodiesel which represents almost a 27% increase in US capacity (Chemical & Engineering News, 2006).

Table 6 presents the current situation for synfuels. South Africa is the world leader of coal and gas-to-liquid production with more than 8 million barrels per year. Other countries are

---

[3] About 470,000 barrels per year or 1,300 barrels per day.

also installing large GTL facilities (Argentina, Indonesia, Egypt, Iran, Nigeria, Qatar, and Trinidad & Tobago) (Ondrey, 2004). There are several different technologies, for which different companies have pilot plants.

Coal will continue to play a key role in the world energy mix. By some estimates, in 2030 coal will meet 22% of global energy needs, essentially the same as today. The electricity sector will be responsible for over 95% of the growth in coal demand, as coal remains the leading fuel for power generation. World proven coal reserves are enormous. Compared with oil and natural gas, they are widely dispersed. Over 40% of the world's 907 billion tones of coal reserves – equal to almost 200 years of production at current rates – is located in OECD countries (IEA, 2004a).

Table 5. Worldwide biofuels production

Country/Region	Fuel	Raw Material	Production
United States	Bioethanol	Corn (major crop[a])	13.4 million tons in 2005[b] (world's largest producer, 27 plants)[c]. 24 ethanol plants are planned[g].
	Biodiesel	Soybean[c] Restaurant waste oil[c]	269,139 tons in 2005[b] (2nd largest producer after EU)[c]
European Union	Bioethanol	Wheat[a,c] Sugar beet[a,c] Barley[a] Potatoes[d]	310,000 tons of bioethanol in 2003[c] Spain is the major producer with 180,000 tons of bioethanol in 2003[c]
	Biodiesel	Rapeseed oil[c] Soybean oil[c]	1.4 million tons of biodiesel in 2003[c]
Brazil	Bioethanol	Sugar cane[e] Eucalyptus[e]	10.1 million tons ethanol from sugar cane produced (second largest producer)[e] 2.2 million tons of ethanol exported in 2004 (world's largest exporter)[c]
	Biodiesel	Soybeans[c]	In 2004 Brazil started to blend 2% biodiesel from soybeans to diesel[c]
China	Biodiesel		Biodiesel is still in research phase, with no large-scale production in practice[c]
	Bioethanol	Cassava[c] Molasses[c] In-land grains[c]	Bioethanol plants under construction with capacity of 1.2 million tons per year[c]
Australia	Bioethanol	Molasses[f] Starch stream[f] Sugar cane[f] Bagasse	121,695 tons per year[f]

a: IEA 2004 b: DOEgenomes.org, 2006a c: Slingerland & Geuns, 2005 d: Grassi, 1999
e: Wright, 2006 f: Dicks et. al., 2004 g: Swenson, 2006

An obvious alternative to synfuels made from natural gas is the direct use of natural gas for transportation purposes. Several countries, especially those rich in gas, have considered developing infrastructure to this effect, and gas-importing countries have also developed such capabilities[4]. The comparative analysis of these competing options is omitted here, mostly because it is a well-known case. Indeed, if natural gas delivery infrastructure (especially via pipelines) is not in existence in the first place, it seems to be much cheaper to transform gas to liquids at the source and then transport the liquids, than transporting the gas

---

[4] For example, natural gas (methane) filling stations and cars (mostly taxis), trucks and buses using compressed natural gas are fairly common in Ukraine, Bulgaria, Armenia and some other Eurasian countries with existing natural gas delivery infrastructure (pipeline networks).

for direct use as transportation fuel. However, where gas networks are already in place to serve *other* markets (power and heat generation, residential gas demand, etc.), setting up methane-filling stations and fleet conversion to direct natural gas use as engine fuel is a viable option. Some costs-per-km comparisons are offered in Section 3 below.

Table 6. GTL and CTL production

Country/Region	Fuel	Raw Material	Production
South Africa	GTL	Natural gas	Petro SA, GTL plant: 36,000 bpd[d]
	CTL	Coal	Sasol's "Secunda" plant produces 160,000 barrels a day of fuel from coal[c]
United States	CTL	Coal	CTL plant is on feasibility stage, Rentech Inc and Peabody Energy have plans for 10,000 to 30,000 bpd CTL plant[e]
	GTL	Natural gas	400 bbl/d plant in Oklahoma[a] 250 bbl/d in Alaska[a]
China	CTL	Coal	Sasol/Shenua/Ningxia, feasibility stage for 2 x 80,000 bpd plant[b]
Nigeria	GTL	Natural gas	Sasol-Chevron/National Nigerian Petroleum Corp. are working to develop a 34,000 bpd GTL plant, expected to run in 2009[c]
Qatar	GTL	Natural gas	Sasol/Qatar Petroleum (QP) 34,000 bpd with the ORYX plant[c] There are plans from SASOL-Chevron to expand ORYX plant to 100,000 bpd capacity[a] Shell/Qatar Petroleum designs plans for 140,000 bpd plant to run on 2009[a] QP/Sasol-Chevron are looking to develop a 130,000 bpd GTL plant to start up in 2010[a]
Malaysia	GTL	Natural gas	Shell operates a 14,700 bpd plant at Bintulu[f]
Australia	GTL	Natural gas	Opportunity progressing by Sasol-Chevron[b]

a: Ondrey, 2004 b: Schaberg, 2005 c: Sasol, GTL, 2006
d: Malan & Aldrich, 2006 e: Rentech, Inc., 2006 f: Shell.com, 2006

Which pathways are the most successful so far?

The most successful pathway for first generation biofuels is ethanol from sugarcane, especially in Brazil. Ethanol production and domestic oil production increases have helped Brazil gain its oil import independence by the end of 2006 (da Silva, 2006).

In the US, bioethanol from corn and biodiesel from soybean are the most popular pathways; this is mainly because of the raw material availability and the compatibility of ethanol with gasoline engines. However, energy requirements and environmental impacts are lighter for biodiesel because the transesterification of oils to biodiesel is a less energy-intensive process and requires also fewer materials than fermentation. It must be highlighted that the success of these pathways is due in part to governmental subsidies, though in Brazil (for example) production systems have been developed so well that direct production subsidies are not needed anymore (Goldemberg et al., 2004). Even in this case, taxes at the pump for ethanol are smaller than the ones for gasoline, accordingly $0.09 per litre for biofuel and $0.42 per litre for gasoline (Luhnow & Samor, 2006).

As for synfuels, current GTL production is larger than CTL (less than 5% of total synfuels produced around the world come from coal) which can be attributed to cleaner technology and larger resources. However, while capital costs are smaller for GTL than CTL, natural gas prices are rising in parallel to crude oil prices. Overall, GTL and CTL manufacturing costs are similar, and their competitiveness to petroleum depends obviously on feedstock prices. For GTL, gas prices have to remain below $1.00 per million BTU to compete with petroleum-based diesel fuel. GTL produced from gas supplied by pipeline is not economically feasible due to the costs associated with its transport. Ideally, GTL-based diesel processed at stranded natural gas sources[5] would have the largest return of investment, e.g., Alaska (California Energy Commission, 2006). Finally, oil prices have to stay above $25 per barrel for CTL to compete, considering that the cost of a synfuel barrel is $23 per barrel of oil equivalent (Li, Y-W., 2004).

Summary: Many countries have started to diversify energy feedstocks in an effort to reduce oil dependence and GHG emissions. Brazil, for instance, has been producing and using bioethanol for 30 years. The US has increased its production of bioethanol, overtaking Brazil as the largest producer, and is also advancing its biodiesel production – from a very low base. Europe is the leader in biodiesel production, but it has a very modest level of ethanol production. Interest in GTL and CTL is growing, especially in countries and regions where coal and gas is abundant but sources are remote. Various companies are pursuing CTL and GTL technologies that differ, especially in the first phase of syngas production.

---

[5] Sources of gas that have no market outlet.

2.2. Biofuels, GTL, CTL – What Main Issues Are Involved?

Why conventional fuels for non-stationary applications should be replaced?

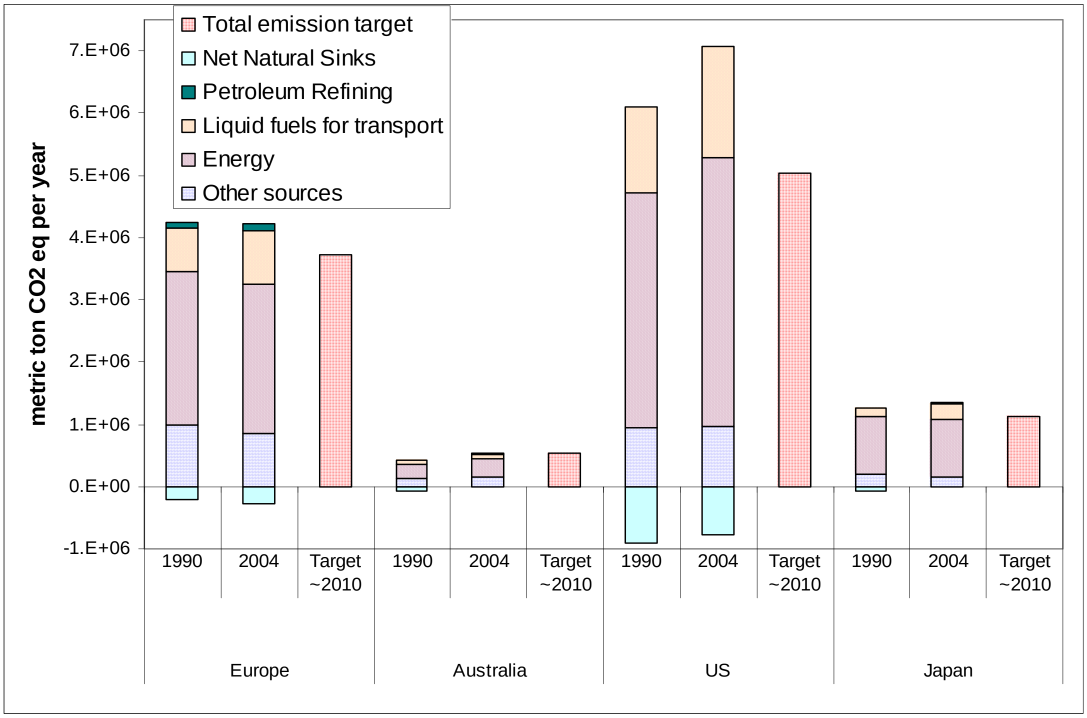
Using a scarce and non-renewable good (petroleum) to satisfy an increasing energy demand has a negative environmental impact (global climate change) and a negative economical impact on non-oil producing nations (deteriorating trade balances).

Pressure from environmental aspects

The Kyoto Protocol calls for industrialised countries and transition economies listed in its Annex I to reduce their greenhouse gas emissions by at least 5% below their 1990 levels on average over 2008-2012 (UNFCCC, 2006a). To achieve this target, a replacement of fossil fuels is of main interest for many countries so they can meet their own national commitments.

Figure 1 shows total greenhouse gas emissions (CO_2, CH_4, and N_2O mainly) for Japan, EU, US, and Australia in 1990, 2004, and their reduction targets for around 2010, as specified in the Kyoto Protocol, which are binding for the signatories only and not for the US and Australia. The contribution by source can be appreciated in this figure. Also, it shows the difference in GHG emissions from 1990 to 2004. This figure indicates that the EU has decreased gas emissions, while especially US and Australia have increased their gas emissions in the past decade. Thus, these international treaties and agreements to reduce emissions are exerting pressure for developing alternative energy sources that can reduce GHG emissions and replace fossil fuels.

Figure 1. Greenhouse gases sources and sinks



(Elaborated with information from National GHG emissions inventory reports 2006 before the UN)

On February 16, 2005, the Kyoto Protocol came into force after the Russian Federation ratified the treaty (UNFCCC, 2006b), though the United States and Australia have announced that they do not intend to do so (IEA, 2004). Despite this negative stance, some internal forces are moving these countries in the direction of the reduction of emissions as well. For example California and the UK have signed an agreement on August 1, 2006 to "become partners in addressing climate change and promoting new clean fuel technologies" (Environment New Services, 2006).

Pressure from increasing consumption and costs

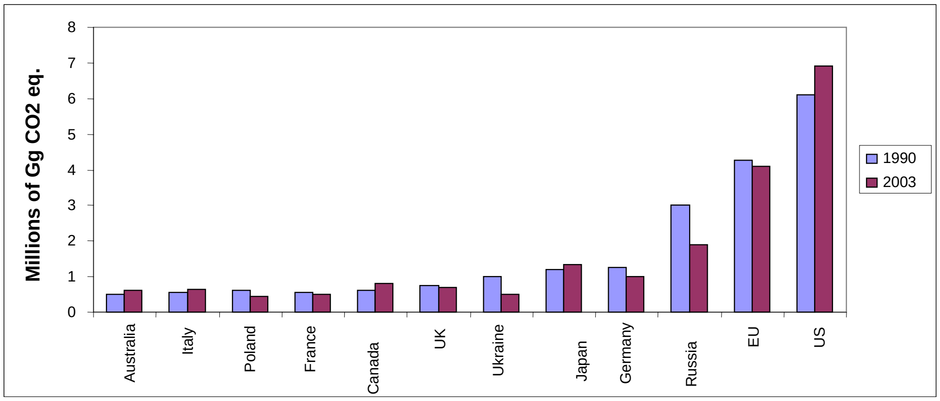
Approximately 23.5% of total energy consumption is allocated to road transportation (see Table 7)[6], which account for the energy input needed to produce petrofuels. Figure 2 depicts greenhouse emissions of several countries. In turn, the rising cost of petroleum-based products is driven by increasing demand, combined with limited production and delivery capacity and concerns about availability of natural resources. Figure 3 shows the growth in world energy demand by source from the 1970s to the 2030s. If one plots the cost of this energy, instead of just the volume demand, the growth is even more dramatic.

Table 7. Transportation-related energy consumption of key markets

	Total Consumption Metric tons oil equivalent (mtoe)	**Road Transport Consumption Metric tons oil equivalent (mtoe)**	**%**
EU[8]	1228503	287009	23.4
US	1540623	497621	32.3
Japan	342126	79373.2	23.2
Australia	72995	21971.5	30.1
Turkey	51785	10201	19.7
China	785435	47912	6.1
Total	**4021467**	**944088**	**23.5**

(Source: IEA, 2004)

Figure 2. Total aggregate GHG emissions of individual Annex I Parties



(Source: UNFCCC, 2005)

---

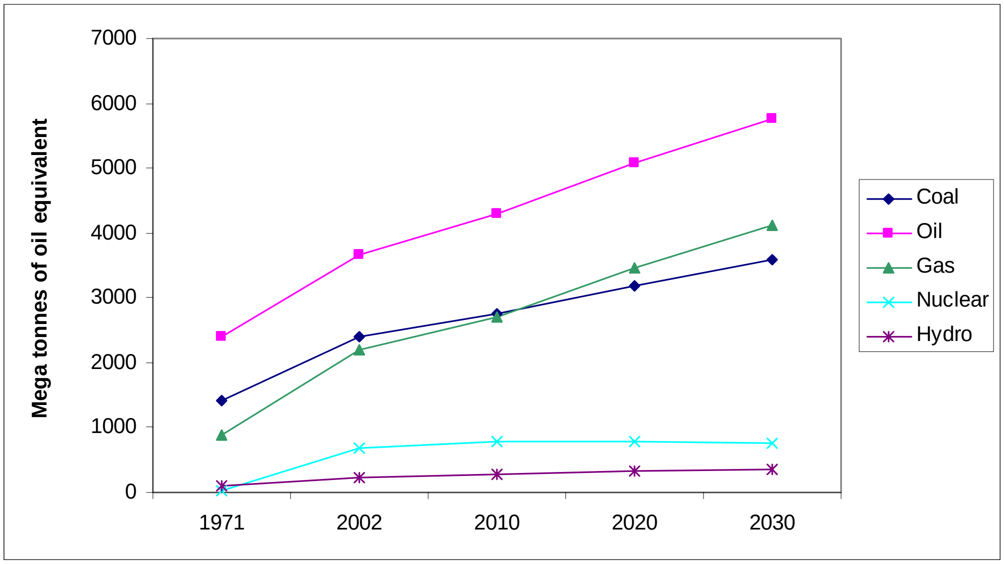
[6] Takes into account the energy needed to produce petroleum-based fuels.

[8] EU includes countries that joined the Union from 2007 (Bulgaria & Romania); Cyprus and Malta were not considered.

According to the IEA (2004), global energy demand grew by 2.9% in 2003 (the fastest increase since 1988 and twice as fast as during the previous five years), mainly driven by burgeoning Asian demand. Demand in China surged by almost 14%, while the North American market expanded by only 0.2%.

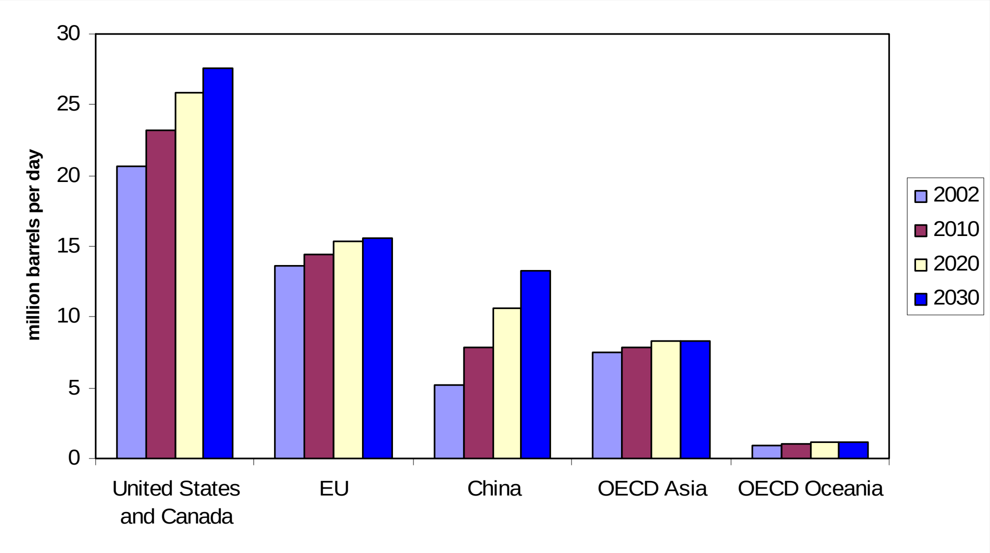
Figure 4 shows oil demand for many key markets around the world and the projection for 2030. Finally, Table 8 shows the targeted emissions of key countries.

Figure 3. World primary energy demand by fuel



(Source: IEA, 2004, corroborated with EIA, 2006)

Figure 4. Projected oil demand by region or country from 2002 to 2030



(Source: IEA, 2004). Note: OECD Asia includes Japan, and OECD Oceania includes Australia.

Table 8. Target emissions for countries included in Annex B to the Kyoto Protocol

Country	Target (2008/12)
EU-15[*], Bulgaria, Czech Republic, Estonia, Latvia, Liechtenstein, Lithuania, Monaco, Romania, Slovakia, Slovenia, Switzerland	-8%
US[***]	-7%**
Canada, Hungary, Japan, Poland	-6%
Croatia	-5%
New Zealand, Russian Federation, Ukraine	0
Norway	+1%
Australia	+8%
Iceland	+10%

* The EU Member States will redistribute their targets among themselves, taking advantage of a scheme under the Protocol known as a “bubble.”
** The US has a different emissions inventory, it would be 3% in terms of Kyoto Protocol.
*** The US has indicated its intention not to ratify the Kyoto Protocol.

(Source UNFCCC, 2006c)

What alternative fuels for non-stationary uses have been chosen to reduce oil dependence?

Of the many alternative fuels proposed, fuels from biological matter sources (mainly biomethanol, bioethanol, biogas and biodiesel) have been considered first because they are renewable and therefore help reducing greenhouse gases emissions (Kaltschmitt, et al., 1997; Puppan, 2002; Reinhardt & Uihlein, 2002; Kadam, 2002; Sheehan, et al., 2004; Tan & Culuba, 2002) and decrease oil dependence. On the other hand, while gas and coal are non-renewable, the main driver for transforming them into synthetic fuels is their plentiful availability, which could also curb petroleum demand. Table 9 shows the most common admixing fuels that have been developed and are in use. Ethanol and methanol are blended with gasoline and biodiesel is blended with diesel of crude oil origin. For the latter, B20 seems to be the current most feasible and favoured option (National Biodiesel Board, 2006), whereas for the former, E85 seems to be gaining popularity[10]. For example, GM and the Ford Motor Company are trying to create the “Midwest Ethanol Corridor” by expanding E85 ethanol fuel availability in Illinois and Missouri in partnership with VeraSun Energy (Green Car Congress, 2006).

Table 9. Admixing categories for biofuels

		Ethanol	Methanol[+]	Biodiesel
Admixed percentage of petroleum-based gasoline or diesel with biofuel	5%	E5	M5	B5
	10%	E10	M10	B10
	20%	E20	M20	B20
	50%	E50	M50	B50
	75%	E75	M75	B75
	85%	E85	M85	B85
	100%			B100*

* In Germany many trucks run on 100% biodiesel
\+ Methanol is not found or is limited in retail markets

---

[10] Blends are named with references to the percentage of the non-petroleum fuel; thus E85 is 85% ethanol, 15% gasoline; B20 is 20% biodiesel, 80% petroleum-based diesel.

Which fuels are still in the stage of research?

- Biofuel from the MixAlco Process[11] is a technology developed in the United States that has a very promising future, but it has not attracted the attention of the governments or investors. It is almost ready to start running but requires support, possibly via tax policies. This mixture of alcohols has more energy output and uses waste from landfills (waste has become a worse environmental problem);
- Feasibility of biomass to liquids (BTL) technologies using lingo-cellulose material has not been fully assessed;
- Bio-oils: This process "burns" (decomposes) biomass without oxygen at temperatures around 500°C. It converts biomass to liquid (bio-oil), gaseous, and solid (charcoal) fractions;
- GTL and CTL technologies use mainly Fischer-Tropsch reactors fed by syngas (mainly a mixture of CO and hydrogen). Different companies are proposing and researching different technologies to produce this syngas;
- Hydrogen and/or fuel cells have been supported but many technical issues have not been adequately addressed yet, i.e., fuel cell robustness or source of hydrogen.

Issues from all perspectives for alternative fuels

Despite the fact that alternative fuels are seen as part of the solution for decreasing oil dependence, reducing greenhouse emissions, and diversifying income, questions about their impact on many areas have not been answered or controversy exists about the answers. Aside from the economic impact, one needs to consider the compliance with emission reduction goals, voluntary and mandated by treaties (Kyoto) and others. Table 10, Table 11, Table 12 and Table 13, provide summaries of the main technical, economic, environmental, and government policy issues.

Summary: Because of the negative environmental effect of fossil fuel use in transportation ("non-stationary") applications, which are around 25% of total energy use, pressure to switch to renewable and clean fuels has mounted. Because the total current use of petroleum-based fuels is large and still rising fast, a move to diversification requires detailed analysis from technical, economic, environmental and government perspectives (Table 10 through Table 13). Many improvements are still needed for current practices in biofuels, CTL and GTL to become mainstream, and new processes are being currently developed to obtain more competitive biofuels using fewer resources (land, energy, water, etc.).

---

[11] A mixture of alcohols with higher energy content can be made using any kind of waste biomass. This is described in Annex II in more detail.

Table 10. Current main *technical* issues for alternative fuels of non-stationary applications

	Pros	Cons	Controversial / Debated	Issues common to all
Bioethanol	• Big diversity of crops for production • Technology available and fairly efficient	• Engine corrosion from high percentage bioethanol or from water • Longer turnaround time (seed-to-fuel) than petrofuels (well-to-fuel) • Cellulosic material still not economically feasible because pre-treatment is very expensive, despite research efforts • Increasing concentration of ethanol in diesel lowers cetane number proportionately • Difficult ignition in mixtures with diesel	• Controversies on energy balance (energy in vs. energy out) to produce bioethanol, mostly from studies done by professors David Pimentel from Cornell University, and Tad Patzek from the University of California	• Use fossil fuels (non-renewable) in the production process • Share of distribution infrastructure with few modifications
Biodiesel	• Technology available and fairly efficient • Better lubricant than petrodiesel; extends work life of engines	• Low yields per hectare compared to bioethanol • Longer turnaround time (seed-to-fuel) than petrofuels (well-to-fuel) • Possible low-temperature engine starting problems when using pure biodiesel	• Controversies on energy balance, as described for bioethanol	
Biomethanol	• Technically feasible	• Not suitable for hot environments because of safety issues (flammability and toxicity[*]) • Poor energy content in comparison with bioethanol and diesel	• Technology costs to mitigate flammability (methanol burns with invisible flame) and toxicity can be too high	
Synfuels	• Compatible with current vehicle engines	• Need of petrofuels for extraction of raw material (natural gas or coal)	• Different technologies for syngas production are being tested (steam reforming, partial oxidation and catalytic partial oxidation and autothermal reforming)	

Table 11. Current main economical issues for alternative fuels of non-stationary applications

	Pros	Cons	Controversial / Debated	Issues common to all
Bioethanol	• Income diversification, i.e., a variety of economic benefits can be derived from ethanol, like new jobs, etc. • Helps developing countries	• Expensive to produce • Dependence on raw material prices	• Economic feasibility	• Food supply could be threatened, and food prices may rise • Uses fossil energy for production (irrigation, harvesting, etc.) • Need of subsidies for feedstocks • Need of tax exemptions • No global market • Land availability for “energy crops” • Switches dependence from oil to biomass or natural gas
Biodiesel	• Income diversification • Gives opportunity for developing countries	• Expensive to produce in comparison to petrodiesel	• Engine performance is not the same as petrodiesel	
GTL / CTL	• Promotes economic diversification in countries with gas and coal resources	• Large investment needed	• More abundant but remote and yet finite resource	

Table 12. Current main issues in governmental policies for alternative fuels of non-stationary applications

	Pros	Cons	Controversial / Debated	Government policy issues common to all
Bioethanol	• Existing efforts to popularise it	• Petroleum companies have too much weight on political decisions	• Loans for new plants construction needed?	• There is encouragement of second generation biofuels development to improve the use of every resource available • Key to reducing energy dependence • Tax exemption for biofuel and vehicles • Encouragement of market share of biofuels
Biodiesel	• Government encourages market share of biodiesel		• Unclear if only sustainable biodiesel should be consumed	
Synfuels	• Key source for reducing oil dependence		• Lack of full support compared to biofuels	

Table 13. Current main Environmental, Health and Safety (EHS) issues for alternative fuels of non-stationary applications

	Pros	Cons	Controversial / Debated	Issues (common to all)
Bioethanol	• Contributes to carbon sequestration due to the use of plants • GHG emissions reduced by 12% in production and combustion	• A small fraction of carbon from soil would be removed every harvest, if cellulose material is transformed into ethanol • Very flammable when mixed with diesel • Increases permeation rate of gasoline to groundwater	• Complete cycle of production could be more prejudicial for human health due to land erosion, more pollution creation	• Erosion • Food supply • Carbon sequestration cycle will be affected • Increase in land-use type changes • Uses pesticides • Uses fertilisers • Deforestation
Biodiesel	• Contributes to carbon sequestration • Reduction in particulate matter (PM), hydrocarbons (HC), & carbon monoxide (CO) in engines • GHG emissions reduced by 41% in production and combustion compared to petroleum-based diesel	• NO_x pollution • Flammability increases when mixed with ethanol		
Biomethanol	• Synfuel combustion produces less particulate matter, hydrocarbons, CO and nitrogen oxides (NOX) and is sulphur-free		• CO_2 emissions from the production of synfuels is larger than that of petroleum-based fuels	

3. Non-petroleum Fuel Economics

3.1. Assessment of Direct Economic Costs / Benefits for Each Pathway / Modality (Capital Cost, Operational Cost, End-user Cost)

The literature analysing costs of the corresponding plants contains discrepancies that are very difficult to resolve without having the original data. In addition, different base for calculations is used in many cases, and the assumptions and sources are not always listed in a complete way. *More detailed and reliable results can only be obtained if a dynamic and rigorous model is constructed taking into account all the steps in detail, which would have the ability to produce the resulting new manufacturing costs each time feedstock, labour, energy and other costs and taxes are changed.*

In addition to the above difficulties, there is the question of how to take into account externalities. For example, Swenson (2006) discusses this issue and criticises existing economic modelling, suggesting that another approach including many yet unacknowledged or emerging externalities, such as heavy water use or air pollution control, should be taken.

Regarding distribution costs, most of the studies consulted assume that existing gasoline pipelines would be used, but the current practice is trucking and mixing at the fuel station, increasing the costs compared to pipeline. This makes difficult the assessment of distribution costs in a simple way. Besides, the American Petroleum Institute claims that mixing at the refinery and using pipelines would introduce water and reduce the octane number of gasoline (API, 2006a).

Finally, although the studies claim that all costs have been taken into account, there is very little information about the specific contribution of other incidental costs (fertilisers, pesticides, machinery, etc.), and how it is calculated.

Despite the shortcomings of the available data, the following sections present available information on costs, with all costs shown, but not including subsidies unless noted. Section 3.7 below addresses the nature of the economic data uncertainties in more detail.

Biofuel capital, operating and manufacturing costs

Table 14 compares costs of biofuel plants. The results correspond to our calculations using information from reports that explicitly show manufacturing costs. It shows that corn ethanol is cheaper than molasses beet ethanol. In turn, the case of China exhibits an unusually high capital cost and low operating cost. The reason is that in the relevant study (Grassi et al., 2002), the bioethanol plant produces also biohydrogen, activated carbon, methanol, and animal feed and the operating costs are not detailed for each product (contrarily to the capital cost and income); however, the operating costs for bioethanol are the fraction corresponding to ethanol of the total income. Finally, biodiesel produced in the US is cheaper than in Europe.

Further analysis on costs cannot be made at this time with the information shown in the open literature due to the different base, time period, and lack of rigorous evidence to support such data. Moreover, final costs are quite sensitive to feedstock costs of biofuel. In addition, plant location should be analysed in better detail because of its impact on transportation costs.

Table 14. Costs of biofuel plants

	Bioethanol				Biodiesel		
Location	**Iowa, USA**	**China**	**USA**	**Alsace, France**	**Europe**	**Georgia, US**	**Germany**
Capacity (million litres)	189	660	420	50	57	63	Not reported
Feedstock	Corn	Sweet sorghum	Sugar beet molasses	Wheat or sugar beets	Vegetable oil	Waste fat, oil, or seed oil	Rape or sunflower seeds
Capital costs (million €)	62.8	928[****]	42	5.5[+]	30	8.2	NA
Operating costs (€/litre)	0.38	0.09[§]	0.55	0.48	0.67	0.34	NA
Manufacturing costs[**] (€/litre)	0.42	0.69	0.64	0.59	0.67	0.36	0.72[++]
Reference	Swenson[*] (2006)	Grassi et al.[*] (2002)	Shapouri[*] (2006)	Toro (2004)	USDA FAS (2003)	Shumaker[*] (2003)	Toro (2004)

Note: Sources do not explicitly take into account subsidies

[*] Originally in US dollars. Converted to Euros using an exchange rate of $1.17 per Euro.

[**] Uses straight, 10 years depreciation.

[***] There are some by-products that can be accounted to reduce final costs.

[****] The plant produces bioethanol, biomethanol, biohydrogen, activated carbon and animal feed. The bioethanol plant capital cost is €360 million.

[§] Operating costs were not detailed for every product, but income was detailed; the percentage of the bioethanol income was obtained and then it was assumed that the same fraction would correspond to the operating costs.

[+] Assumed: the author only specified depreciation in production basis. The biofuel production technology was not mentioned.

[++] Manufacturing costs were explicitly given, but operating costs breakdown is difficult to follow.

Table 15 shows the production costs of wheat and beet crops intended to produce bioethanol in the EU. Unlike those of Table 14, data are from the same source, which makes them more reliable for comparison. Table 16 provides the cost per GJ from data from the Institute of Transport Research et al. (2003). One can observe a discrepancy for the cost per gigajoule of energy for beet and wheat-based ethanol in Table 15 and in Table 16, being 28€/GJ and 41€/GJ for wheat, whereas for sugar beets it is 28.4€/GJ and 35€/GJ. Such discrepancies may be caused by different crop yield per area estimates and different year basis. Costs of biofuels in terms of energy generated are very sensitive to the changes of efficiency of land by crop. For this reason, conservative comparisons cannot be made using this kind of information. Estimates should be made for specific smaller and strategic zones within the same time frame, hence overall efficiencies could be compared and its economic feasibility accurately assessed.

Table 15. Bioethanol costs in the EU-25 + Bulgaria, Romania

	Wheat based			Beet based		
Costs	€/L	€/GJ	€/ton	€/L	€/GJ	€/ton
Net feedstock	0.25	11.8	493	0.23	10.9	454
Conversion and blending	0.33	15.7	652	0.27	12.8	533
Distribution	0.01	0.5	20	0.1	4.7	197
Total costs at petrol station	**0.59**	**28**	**1165**	**0.6**	**28.4**	**1184**

(Source: EUBIA, 2006, with information from BTG 2004)

Table 16. Total output cost of production for biofuels in the EU

Fuel	Raw Material	Total output cost of production (€/GJ)
Biodiesel	Vegetable oil from rape seed	15
	Methyl ester from rape seed oil	20
Ethanol	Sugar beet	35
	Corn (starch to sugar, fermentation)	38
	Cereals (grains, winter wheat)	41
	Potatoes	37

(Source: Institute of Transport Research et al., 2003)

Is it feasible to reduce costs by increasing scale?

Some potential to reduce costs appears to be possible by increasing scale and carefully choosing locations. The scale reaches its limitation in the size of the fermenters. The optimum size of fermenters is illustrated by the fact that the cost of producing ethanol from corn in the US is lowest in medium-sized plants, and not in large plants, which could be in part attributed to the fact that for mid-sized plants harvesting sites are closer to the plant site (ethanol is cheaper to transport than feedstock). In addition, opportunities for decreasing processing costs may be exploited by using by-products to provide energy for the plants (DFT, 2004). The emerging concept of biorefineries also provides opportunities to reduce costs. Biorefineries are facilities that target a synergistic production of a variety of products, which includes sharing surpluses of energy (this is further covered in Section 5 below).

Synfuels

Table 17 shows a comparison of costs of Fischer-Tropsch (GTL) plants with and without CO_2 abatement and using three different technologies (Marsh et. al., 2003). The plant location is close to a remote source of gas and the accuracy of the data is +/-30%. Finally, the source does not clarify to which country does the pricing correspond to.

Table 17. Comparison of costs of 10,000 barrels per day Fischer-Tropsch synthesis plants

	O_2 blown*; slurry reactor[§]		**O_2 blown*; fixed bed reactor[¤]**		**Air blown*; fixed bed reactor[¤]**	
	No capture	CO_2 capture	No capture	CO_2 Capture	No capture	CO_2 capture
Capital cost (million €)	296	332	333	381	332	366
Annual cost (million €)	62	71	67	77	75	84
Product cost (€/l)	0.13	0.15	0.14	0.16	0.16	0.18
Cost of CO_2 capture (€/t CO_2)	NA	22.9	NA	19.4	NA	25.6

* “Oxygen” and “air-blown” refer to the relevant oxidiser used in the first stage of the Fischer-Tropsch process to produce synthesis gas under possible technology variations.

[§] The slurry reactor transforms the syngas by “bubbling” it through slurry with suspended catalyst.

[¤] The fixed bed reactor transforms the syngas by passing the gas through a fixed bed of catalyst pellets.

Note: Prices where originally in US Dollars and where changed to Euro dividing by a factor of 1.17.

(Source: Marsh et al., 2003)

In addition to the variants of Fischer-Tropsch reactors, several companies are developing different syngas production units, through traditional steam reforming (BP and Petro SA), non-catalytic partial oxidation (Shell), catalytic partial oxidation (ConocoPhillips) and autothermal reforming (Haldor Topsoe/Sasol and Syntroleum). All these companies have small pilot units to research pending technical issues (carbon and soot formation, scale-up issues, corrosion, etc.).

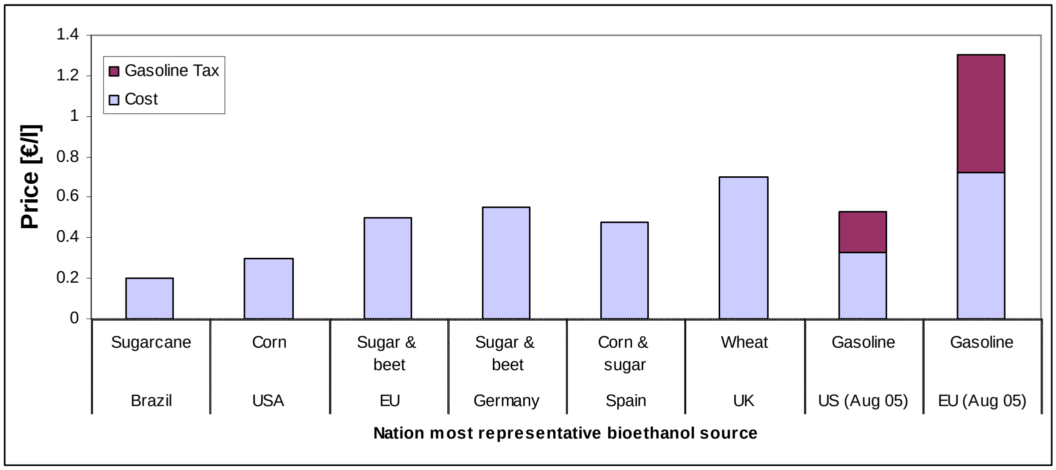
Energy from hot gases can be recovered and used to co-generate electricity which would increase capital costs but decrease unit production costs. Steynberg & Nel (2004) proposed to produce synfuels and electricity at a ratio of 8:1 (8 GJ in synfuel form : 1 GJ electricity). Yamashita & Barreto (2003) and Williams & Larson (2003) claim that unit production costs could thus be cut by 10%. This is illustrated in Table 17, which uses data from Marsh and co-workers (2003), and also compares the prices against diesel fuel and gasoline, but at 2003 costs. In addition, it is not explained in the source how these numbers were calculated or on what basis.

Summary: Cost assessments are very difficult to verify and comparisons are difficult to make due to different basis for calculations. Complete “seed to wheels” and “well to wheels” robust models detailing various aspects of the technologies are needed, as well as details of the associated supply chains, to arrive at appropriate decision making. For the key markets selected for this study, the most competitive crops for production of ethanol are corn for the United States and sugar beet and wheat for Europe, but globally sugar cane is the best. For biodiesel, rape and sunflower seeds are the best crops in the EU, whereas for the US soybean is best.

3.2. Assessment of Economic Competitiveness to Petroleum-based Fuels

Figure 5 and Figure 6 show the relative prices of bioethanol and biodiesel respectively in different countries and for the corresponding crops used as raw material. Figure 5 clearly shows that in the EU, tax exemptions allow entry to the market for almost all "first generation" crop-based bioethanol. In contrast, in the US only corn and in Brazil only sugarcane-based "first generation" bioethanol are competitive. The situation is not quite the same for biodiesel, especially for the case of the EU in which taxation produces a big difference in price.

Figure 5. Relative price of bioethanol production in different countries



(Source: Herrera, 2006 with information from Imprimatur Capital)

It is clear that tax exemptions are the current main tool used to make biofuels competitive to fossil fuels. Moreover, the MTBE[12] ban has increased the demand for ethanol as a gasoline oxygenate substitute. In addition to the fuel consumption tax exemptions, there are other incentives: Consumers in the US who purchase a new clean-fuel vehicle[13] may apply for a tax deduction of up to $2,000 (Slingerland & van Geuns, 2005).

The case of Brazil is often cited as an example to follow. Brazil is enthusiastic about its ethanol program because of many factors. For instance, the cost of producing ethanol in Brazil is about $1 per gallon, in comparison to the cost of gasoline of about $1.50 per gallon. Therefore, it is cheaper in Brazil to drive on ethanol even though ethanol gives less mileage than gasoline per same volume of fuel. Another fact is the advantage of having the right conditions to produce ethanol in Brazil: a warm climate, plenty of land, rain, and relatively cheap labour. Also, to comply with the Kyoto Protocol, countries like Japan and Sweden buy ethanol from Brazil, which has given Brazilian ethanol exports a major push (Luhnow & Samor, 2006). When the ethanol program started in Brazil (early 1970s), the government gave sugar companies cut-rate loans to build up ethanol plants and guarantee

---

[12] Methyl tertiary-butyl ester, a chemical compound which contains oxygen and is often added to gasoline to boost its octane rating or to meet clean fuel oxygen requirements.

[13] One that uses as fuel natural gas, liquefied natural gas, liquefied petroleum gas, hydrogen, alcohol-gasoline mixture, or is electrical or hybrid.

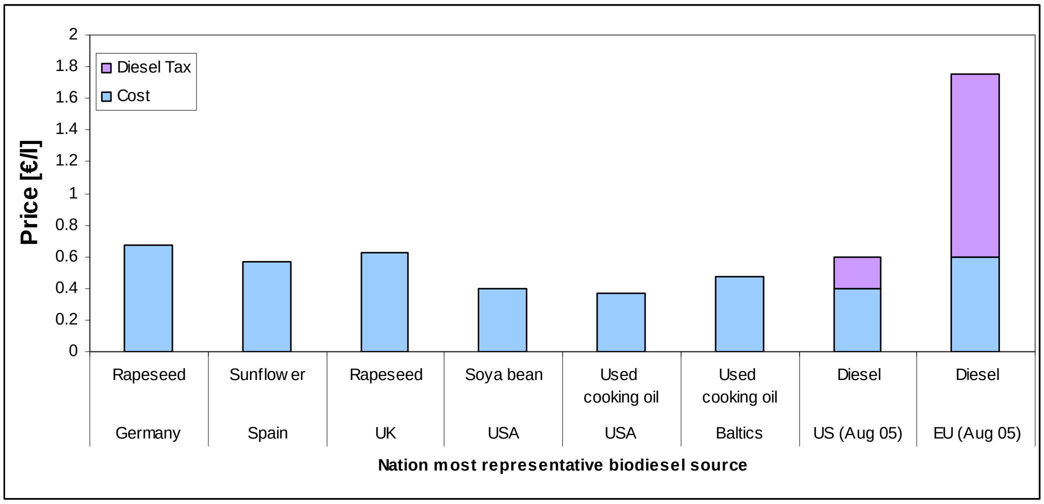
prices, but in the late 1990s the Brazilian government stopped the subsidies forcing sugar producers to lower costs and to be more efficient (Luhnow & Samor, 2006).

Another country that could develop biofuels in the same way as Brazil is Malaysia. This country is a major producer of palm oil, which is cheaper and of better quality than biodiesel obtained from rape seed, sunflower and beef-tallow (API, 2006c).

Whether or not biofuels can evolve into more than marginal alternative fuels and at what pace depends largely on the evolution of the oil market. Between the factors that affect oil prices are oil reserves, political stability of oil producing countries, investment in production capacity, energy demand growth (Slingerland & van Geuns, 2005). Recent high oil prices have enhanced the competitiveness of both biofuels and synfuels.

In Brazil, ethanol costs and prices have fluctuated but the overall trend is going down. Such fluctuation is due to changes of government policies and subsidies, weather conditions, and demand of feedstock for other purposes. In fact, in Brazil ethanol can be competitive against gasoline if oil prices stay over $25 per barrel (IEA, 2004). In the United States, ethanol prices have increased considerably over the last 10 years, but in the first half of 2006 prices started to decrease (OXY-FUEL News Price Report, 2006), and future price trends are uncertain.

Figure 6. Relative price of biodiesel in different countries



(Source: Herrera, 2006: with information from Imprimatur Capital)

Table 18 shows the different cost per kilometer and compares them with liquefied natural gas (LNG). Transportation costs derived from using synfuels (¢/km) are smaller, which may indicate that transporting natural gas (in LNG form) from remote locations is more expensive than producing synfuels and transporting them to end-user locations. This has also been pointed out by Aseeri and Bagajewicz (2004). As previously mentioned, synfuels can be competitive if prices of oil are above the $20-25 per barrel. This can also be inferred from Table 19, which compares costs assuming the diesel is produced at the source location. Also, a 50% decrease in manufacturing costs for synfuels has been observed since 1990 (Dieselnet.com, 2002).

Table 18. Comparison of the cost of energy and cost per km for liquefied natural gas (LNG)[14] and synfuels with and without CO_2 capture

	Diesel (reference)	F-T w/o capture	F-T with capture	LNG w/o CO_2 capture	LNG with CO_2 capture	Gasoline (reference)
Fuel cost ($/GJ)	6.8	7.4	8.1	9.0	9.2	7.2
Fuel cost (¢/km)	1.2	1.3	1.4	2.0	2.0	1.5

(Source: Marsh et al., 2003)

Table 19. Costs comparison between syndiesel and petrodiesel at 2002 prices

Cost Component +	Refinery	GTL
Natural gas (@$0.50/MMBtu)		US$ 4.00
+ Crude oil (@$17/Bbl)	US$ 17.00	
+ Operating costs	US$ 2.50	US$ 3.00
Total cash costs	US$ 19.50	US$ 7.00
+ Capital recovery, taxes	US$ 6.50	US$ 12.00
Total Production Cost (US$/barrel)	**US$ 26.00**	**US$ 19.00**

(Source: Dieselnet.com, 2006)

+ *These costs are assumed at the well (usually stranded locations for gas).*

3.3. Return on Investment

Some companies and researchers have published their estimates of return on investment. For bioethanol it ranges between 15 and 20% (Swenson, 2006; Grassi et al., 2002). No published open data for biodiesel, GTL and CTL was found. Independent assessment of these cannot be made using the existing information at the time when these guidelines were developed, because of the aforementioned large dispersion of conflicting data.

Summary: To date, studies have shown that biofuels are competitive at relatively high oil prices. However, the impact of subsidies has not yet been addressed in the open literature. Moreover, tropical crops such as sugar cane and palm oil are by far the most competitive biofuel in cost and quality compared to petrofuels. Competitiveness of all the reviewed alternative fuels in this study is enhanced when oil prices increase. Synfuels were found feasible if oil prices are above $25 per barrel. For the Brazilian case, ethanol would remain competitive also if oil prices stay above $25 per barrel.

---

[14] LNG is natural gas liquefied by high pressure and/or low temperature, whereas synfuel is a liquid produced from natural gas by a chemical reaction.

3.4. Assessment of Energy Efficiency for Each Pathway / Modality

In Table 20, properties related to fuel efficiency are shown for different fuels. The intrinsic energy content is the energy that a litre of biofuel could contain when burned, but it does not account for engine and transmission efficiency. The octane number is a measure of the anti-knocking properties of gasoline and the cetane number indicates the capacity of a fuel to auto-ignite under compression. Finally, the mass of air needed to burn a kilogram of fuel is shown. There is a difference in the mileage obtained from fossil fuels and that of biofuels. For example, the energy content of ethanol-diesel blends decreases by approximately 2% for each 5% of ethanol added (by volume), assuming that any other additive included in the blend has the same energy content as diesel fuel (Hansen et al., 2005).

Table 20. Properties of different fuels

	Intrinsic energy content (MJ/L)	Octane number (MON)[♥]	Cetane number	Kg of air necessary to burn a kg of fuel
Gasoline	30.4[b]	86 [b]	8.0[b]	14.7
Bioethanol E100	21.2 [b]	92 [b]	11.0[b]	9.0
Biomethanol M85	15.6 [b]	92 [b]	5[a]	6.5
Diesel No. 2	35.7 [b]	8.0 [b]	40.0[b]	14.5
Biodiesel B100	32.6 [b]	~25	46.0	12.3
Syndiesel	34.3 [a]	-	~74[a]	N/A

a: Grassi, 2001;
b: EUBIA, 2006;
♥: MON – motor octane number, as opposed to research octane number (RON).
MON is typically about 10 units lower than RON.

Table 21 shows the ratio between energy obtained and energy input. However, the same problem as with costs appears here: there is a lot of variability in the methods and types of data accounting for energy inputs and also in energy efficiencies reporting of machinery and utilities. Therefore, estimates differ – sometimes significantly.

Table 21. Energy balance for different crop production

Country	Crop	GJ output / GJ input
Brazil	Sugar cane ethanol	7.9
UK	Sugar beet ethanol	2
	Wheat straw	5.2
USA	Corn ethanol	1.3
	Corn stover ethanol	5.2
	Gasoline (Minnesota Department of Agriculture (2002)	4.12

(Source: Blottnitz & Curran, 2006)

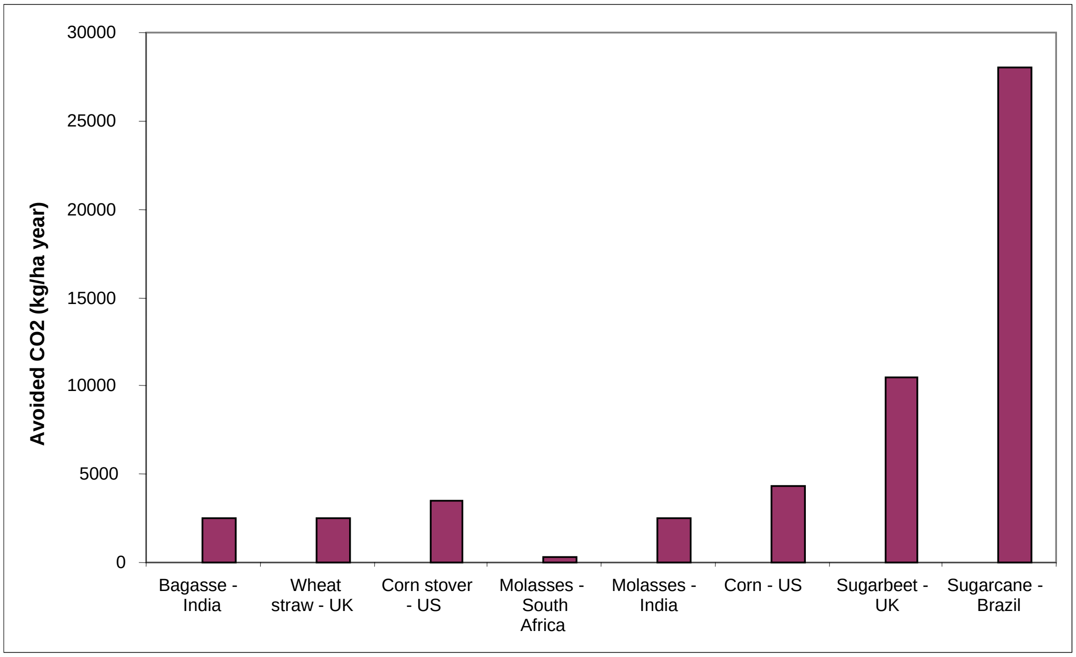
Summary: Energy efficiency could not be accurately assessed at the time when these guidelines were prepared because of the uncertainty of the data published in the open literature. The uncertainty is due to the different methods and scope in evaluating energy inputs. We conclude that a standardised model for every pathway and each biofuel is needed; also energy inputs for petroleum-based fuels and synfuels need to be measured using the same approach as for assessing the biofuels' energy balance.

3.5. Assessment of Greenhouse Gas Emissions for Each Pathway / Modality

3.5.1. How much GHG can be avoided during production?

Blottnitz and Curran (2006) have reviewed 47 published assessments that compare bioethanol systems to conventional fuel on a life-cycle assessment, and presented an evaluation of avoided greenhouse gas emissions per hectare cropped per year for bioethanol production. These results are shown in Figure 7. They exhibit a very noticeable variability due to different agricultural and processing practices, which were not specified in the assessment. Finally, Table 22 provides information on the emissions for different fuels per GJ of intrinsic energy content.[15]

Figure 7. Avoided GHG emissions for different bioethanol systems



(Source: Blottnitz & Curran, 2006)

Table 22. CO_2 emissions for biofuels

Fuel	Raw material	CO_2 emissions (kg/GJ)
Biodiesel	Vegetable oil from rape seed	20
	Methyl ester from rape seed oil	24
Bioethanol	Sugar beet	24
	Corn (starch to sugar, fermentation)	65
	Cereals (grains, winter wheat)	60
	Potatoes	69

(Institute of Transport Research, et al. 2003)

---

[15] Intrinsic energy content is the energy accounted when the material is burnt.

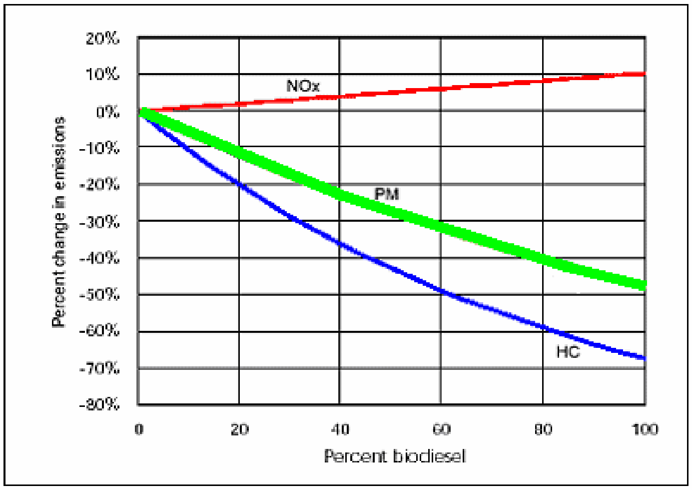
3.5.2. Overall cycle GHG emissions (well-to-wheels, seed-to-wheels)

For bioethanol, Wang et al. (2004) conducted a study of vehicles combusting unleaded gasoline and ethanol, running for a long time on real roads. The main exhaust emissions (hydrocarbons, CO and NO_x) were analysed. When burning unleaded gasoline, the three main pollutants from vehicles with three-way catalytic converter were found to satisfy or nearly reach Europe Exhaust First Standard. After switching to ethanol-gasoline mixture, pollutants were found to be all within Europe Exhaust First Standard or to nearly reach Europe Exhaust Second Standard. In particular, CO drastically decreased by about thirty percent, while hydrocarbons and NOx decreased by about 18% and 10%, respectively. Finally, ethanol-containing gasoline was found to have other performance advantages: a slight cleaning function of injectors, a slower deterioration of engines leading to lower CO and hydrocarbon emissions, as well as a longer operating life-span of catalytic converters.

For biodiesel, Figure 8 compares the well-to-wheel overall emissions. Note that particulate matter (PM) and unburnt hydrocarbons (HC) emissions diminish when using biodiesel. Notably, NO_x emissions increase, whereas the rest decrease.

Biofuels would reduce GHG emissions *if and only if* selected production practices are followed from cultivation to fuel use. Professor Dale (Michigan State University) stated that agricultural management practices need to be reviewed to be able to reduce GHG emissions (Schubert, 2006); this was also corroborated by Shell Renewables executive vice-president Sweeney (Sweeney, 2006). Concerns regarding use of pesticides, fertilisers, deforestation, and biodiversity impacts need to be addressed.

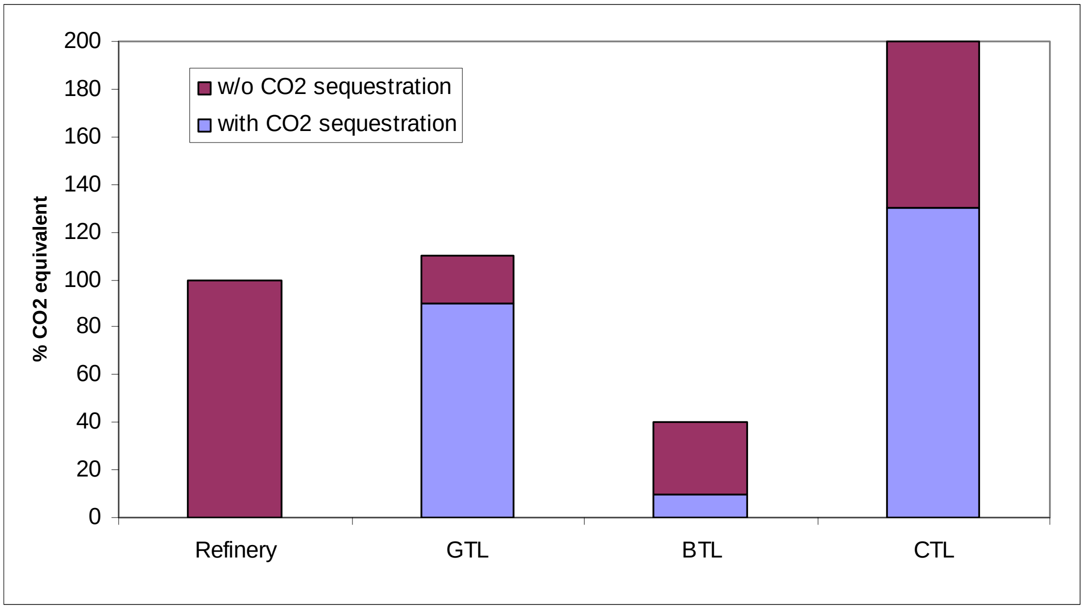
Figure 8. Overall cycle emissions for biodiesel



(Source: EPA, 2002)

Figure 9 compares the well-to-wheels overall emissions for different fuels (ASFE, 2006). GTL can compete emissions-wise with petroleum-based fuels only if CO_2 sequestration is performed. In turn, BTL is projected to have a low value of emissions because of the carbon fixation action of vegetation. In addition, CO_2 sequestration is projected to reduce it further to levels close to 10% from the initial one. Finally, CTL does not seem to show advantages over petroleum-based fuel levels regarding GHG emissions.

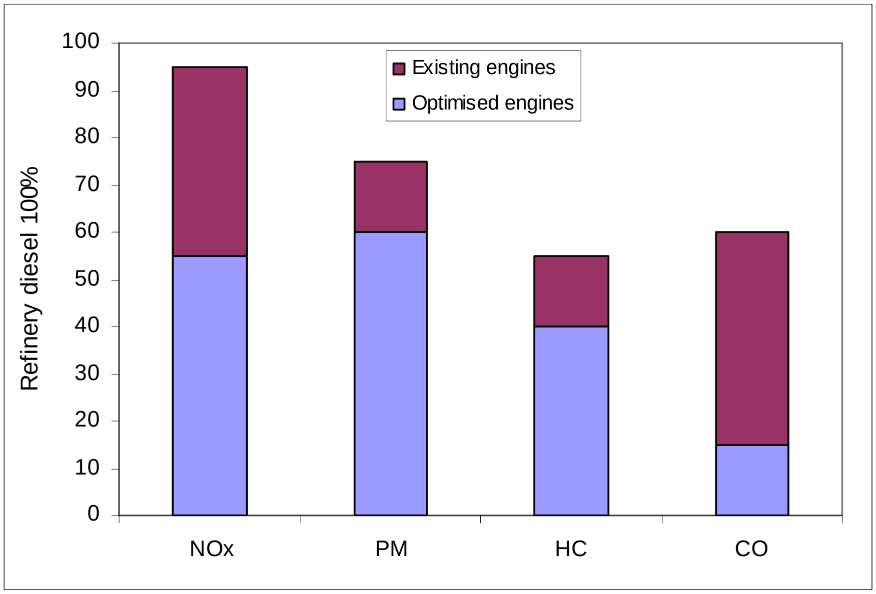
Figure 9. CO_2 overall cycle emissions for different fuels, using different pathways



(Source: ASFE, 2006)

Figure 10 compares emission reductions at engine exhaust for various contaminants when using petroleum-based diesel and syndiesel (ASFE, 2006). The GTL technology produces a high quality, ultra clean fuel which provides an emissions benefit between 40–60% (PM, HC, CO) for light diesel vehicles and 5–30% benefit for heavy duty diesel vehicles (Clark et al., 2002).

Figure 10. Comparison of emissions between petroleum-based diesel and syndiesel



(Source: ASFE, 2006)

Shell commissioned a study by Price Waterhouse Coopers to evaluate all emissions associated with the production and use of distillates derived from a typical crude oil refinery and a GTL plant. The study concluded that the impact of the Shell GTL system has less global warming potential than a refinery system. The GTL system produces approximately as much CO_2 as an oil refinery system during production, but less during fuel use, yielding a lower total amount of CO_2 emissions for the GTL system. For the CTL case, synfuels production causes 25% more CO_2 emissions than petroleum-based fuel manufacturing as one can observe in Figure 10.

Summary: Main exhaust emissions (hydrocarbons, CO and NO_x) were analysed for the different fuels. For ethanol, pollutants were all within the requirements of Europe Exhaust Standard First or nearly satisfied Europe Exhaust Second Standard. Notably, for biodiesel NO_x emissions increase, whereas the rest decrease. Biofuels would reduce GHG emissions *if and only if* selected production practices are followed from cultivation to fuel use. Finally, manufacturing GTL produces more CO_2 than an oil refinery, but less during fuel use, resulting in a smaller total amount of CO_2 emissions compared to petroleum-based fuels.

3.6. Assessment of Land Use and Alternative Crops for Each Pathway / Modality

3.6.1. Bioethanol yield for different crops

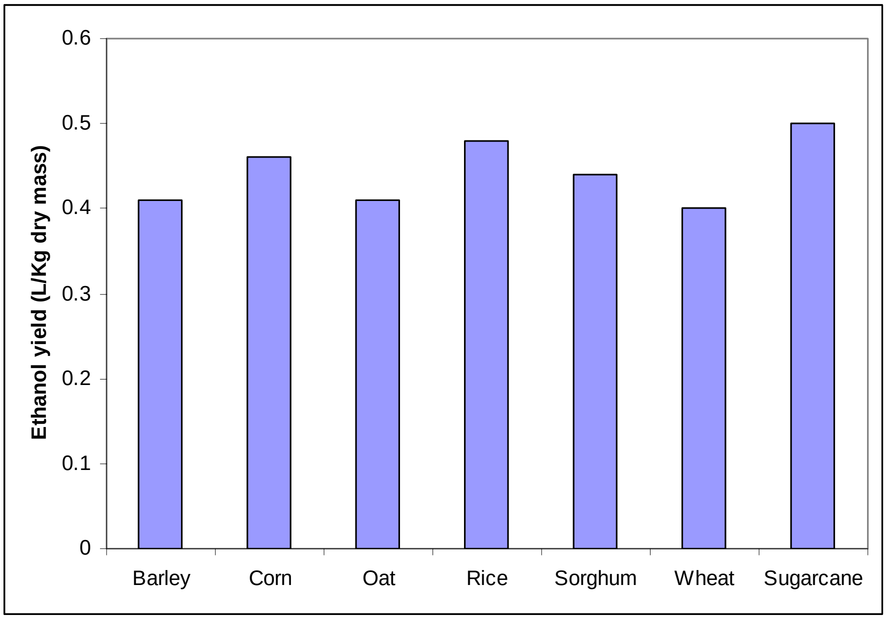
Figure 11 shows the yield of ethanol for different crops. The yield depends on the zone of the world in which ethanol is produced, even for the same crop. Variations of yields may exist if ecological regions or agricultural techniques are different.

3.6.2. Land use

Land, especially of good quality that can be used to produce bioenergy, is scarce and could limit the supply and competitiveness of "first generation" bioenergy significantly (Green, 2000). This scarcity of land is caused by the competition between the production of food, biomaterial and bioenergy on available agricultural and forestry areas and other competing land uses, e.g., urbanisation and nature development (Goldemberg, 2000).

Reaching maximum rates of biofuel supply from corn and soybeans is unlikely because these crops are major contributors to human food supplies through livestock feed and direct consumption (e.g., high-fructose corn syrup and soybean oil). Devoting *all* 2005 US corn and soybean production to ethanol and biodiesel would have an offset of just 12% and 6% of US gasoline and diesel demand, respectively. However, *because of the fossil energy required to produce ethanol and biodiesel, this change would provide a net energy gain equivalent to just 2.4% and 2.9% of US gasoline and diesel consumption, respectively.*

Figure 11. Ethanol yield for different crop composition



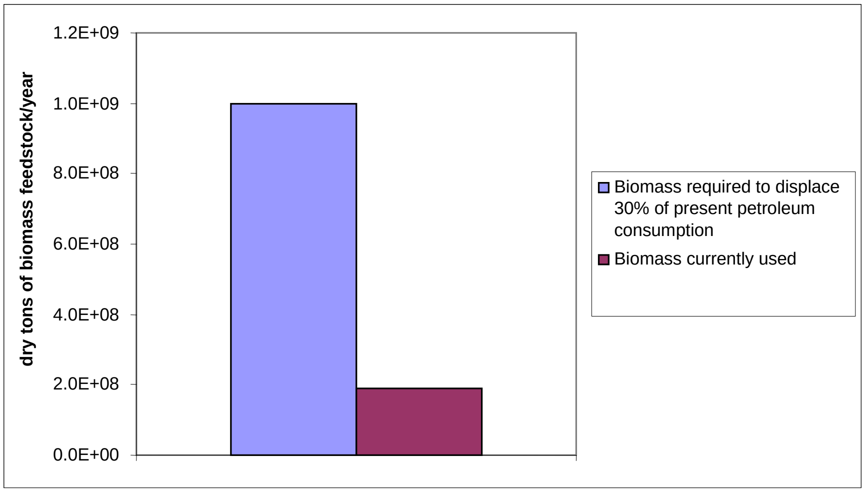
(Source: Kim & Dale, 2004)

Energy gains from "second generation" biofuels are potentially bigger. If, for example, world-wide wasted crop is used as feedstock for bioethanol, the global gasoline production could be reduced by 32% if used in E85 fuel mixture (Kim & Dale, 2004). However, *soil erosion* that would result of taking out all the biomass from the crop fields can cause an environmental problem. Furthermore, efficient collection of crop waste needs to be addressed in further detail in order to determine the optimal agricultural practice.

About 6 to 9 million dry tons of biomass is currently used in the US for the production of a variety of industrial and consumer bioproducts that directly displace petroleum-based feedstocks. The total annual consumption of biomass feedstock for bioenergy and bioproducts together currently approaches 190 million dry tons. According to Perlack et al. (2005), the goal of displacing 30% of the US present petroleum consumption can be achieved looking at just forestland and agricultural land. Figure 12 shows the actual biomass used in the United States and the biomass resources needed in order to produce a sustainable supply of biomass sufficient to displace 30% or more of the country’s present petroleum consumption by producing from biomass several energy sources as bioethanol, biodiesel, etc. Such a goal would require approximately 1 billion dry tons of biomass feedstock per year.

The land base of the US is some 2,263 million acres, from which 33% is classified as forestland, 26% as grassland pasture and range, 20% as cropland, 8% as special uses (e.g., public facilities), and 13% as miscellaneous uses such as urban areas, swamps, and deserts (Perlack et al., 2005). Perlack et al. (2005) state that only modest land use changes would be needed to achieve the above goal. It is, however, unclear if all these changes are feasible when all factors are considered (political, regulatory, etc.). The modest changes include the conversion of 40 to 60 million acres to perennial crop production, depending on moderate or high yield increases, respectively. Also, woody crops produced for fibre would have to be expanded from 0.1 million acres to 5 million acres. However, Perlack et al. (2005) did not study further the feasibility of such changes and they stated that it is extremely difficult to assess such feasibility due to the lack of accurate data and variations of agricultural production.

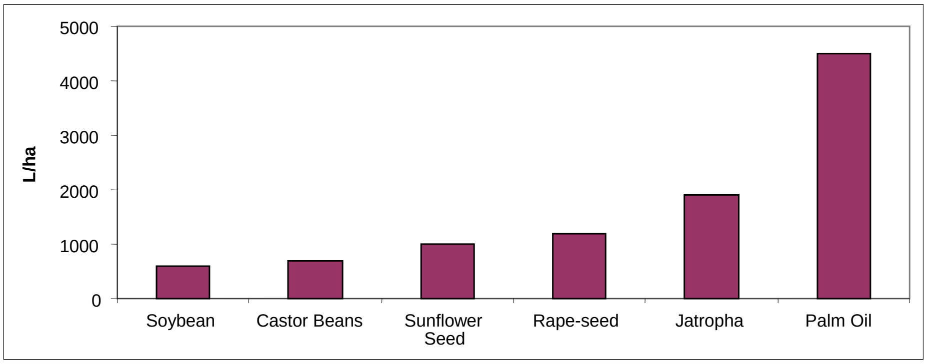
Figure 12. Dry tons of biomass needed to displace 30% of current US oil consumption



(Source: Perlack et al., 2005)

According to (Hill et al., 2006), there is a yield of 3,632 litres/ha for corn grain to produce ethanol, and 544 litres/ha for soybean to produce biodiesel. Figure 13 and show the volume produced per hectare of crop for ethanol and biodiesel, respectively.

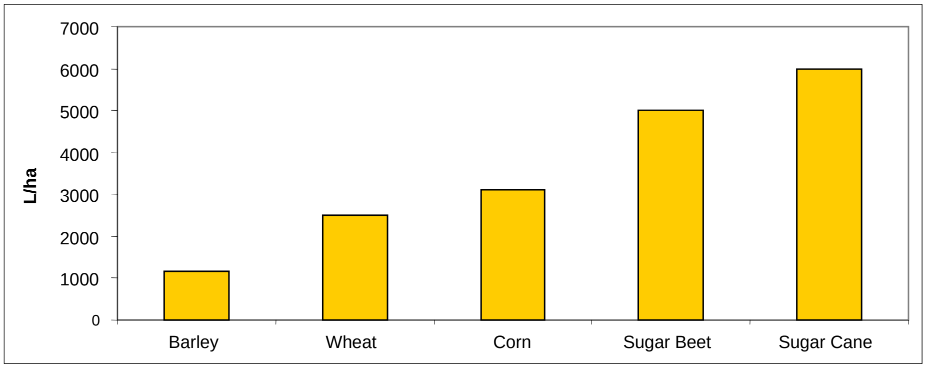
Figure 13. Biofuel yield of selected biodiesel feedstock



(Source: World Watch Institute, 2006)

Recently, the European Environmental Agency (EEA, 2006) concluded that significant amounts of biomass can technically be available to support the 5.75% biofuels goal for 2010 and the 15-16% of the energy projected for 2030. The environmental assumptions made to conclude so were: (a) at least 30% of the agricultural land is dedicated to “environmentally-oriented farming” in 2030 in every Member State (except for Belgium, Luxembourg, Malta, the Netherlands, where 20% was assumed); (b) extensively cultivated agricultural areas are maintained: grassland, olive groves and dehesas (land covered with grass used for pasture) are not transformed into arable land; (c) approximately 3% of the intensively cultivated agricultural land is set aside for establishing ecological compensation areas by 2030; (d) bioenergy crops with low environmental pressures are used; (e) current protected forest areas are maintained; residue removal or complementary fellings (timber cut down during one season) are excluded in these areas; (f) forest residue removal rate is adapted to local site suitability, and foliage and roots are not removed at all; (g) complementary fellings are restricted by an increased share of protected forest areas and deadwood; (h) ambitious waste minimisation strategies are applied. However, the economical feasibility of these assumptions was not addressed (EEA, 2006).

Figure 14. Biofuel yield of selected bioethanol feedstock



(Source: World Watch Institute, 2006)

Japan has little land availability and land re-allocation possibilities are lesser. However, there is still a possibility that Japan can use waste crop residues or other organic materials to reduce oil supply (USDA FAS, 2006). Finally, Demirbas (2001) states that biomass can be the most important renewable energy source for Turkey.

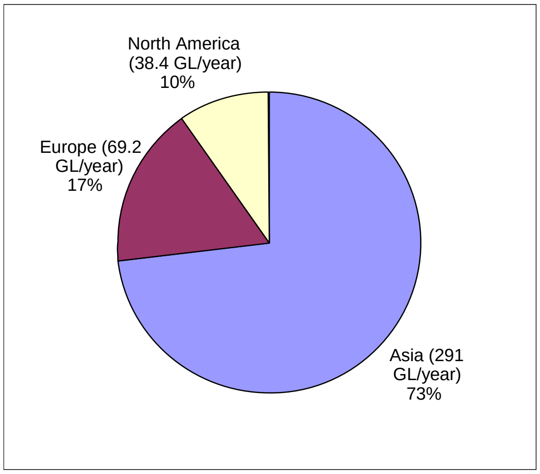
3.6.3. Abandoned Land Potential

Abandoned cultivable lands in industrialised countries are a common phenomenon in recent years (MacDonald et al., 2000; Eetvelde & Antrop, 2004; Kristensen et al., 2004). Biofuel agriculture may become an option when abundant land is available and may compete with the conversion of abandoned agricultural lands to nature (Verburg et al., 2006). However, there is some risk associated for the food industry if biofuels are produced massively, both volume-wise and price-wise. According to Mark Lynch, an analyst at Goldman Sachs, the rapid expansion of biofuels is bad news for food processors: “We estimate that to achieve a 20-80 biofuels/fossil fuel mix would use at least 87 per cent of current crop land in the UK. Even a more modest 5.75 per cent target would use 26 per cent.” (Mortished, 2006). No study has addressed yet land use scenarios for land dedicated to biofuels, food and nature.[16] This is mainly because of the lack of data on the regional agricultural production yields and the changing demand, whose estimates would have a considerable error (Verburg et al., 2006).

3.6.4. Global potential for bioethanol production from wasted crop

About 73.9 million metric tonnes of dry wasted crop in the world has the potential to produce 491 billion litres/year of bioethanol. This could replace about 32% of global gasoline production if used in E85 fuel mixture in mid-sized cars (Kim & Dale, 2004). Figure 15 shows the potential distribution of global bioethanol production using wasted crop. Figure 16 shows the forecasted potential for bioethanol production from different crops wastes, based on the global annual production.

Figure 15. Distribution of the global potential yearly production of bioethanol using wasted crop



(Source: Reijnders & Huijbregts, 2006)

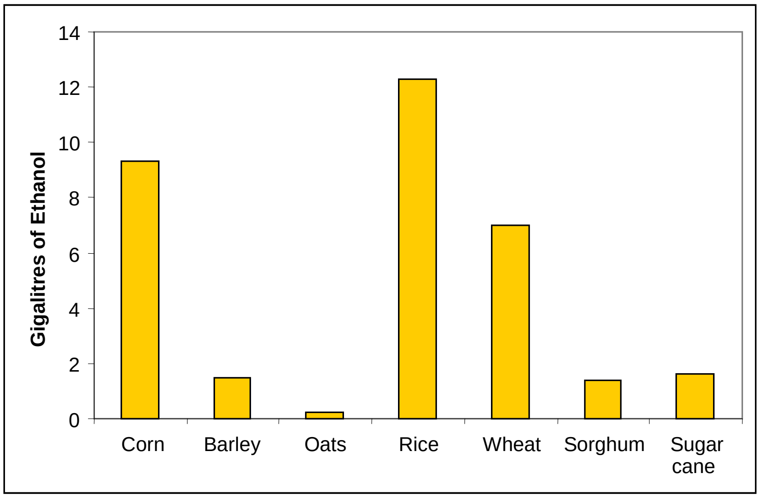
Rice straw is potentially the most favourable “second generation” biofuel feedstock, and the next most favourable raw materials in this generation are wheat straw, corn stover and sugar cane bagasse, in terms of the quantity of biomass available. These four feedstocks can produce 418 Gl of bioethanol per year using the world-wide biomass availability from

---

[16] Land dedicated to nature: land regions protected by law dedicated exclusively for maintaining ecologic diversity.

wasted and residue crops (Kim & Dale, 2004). However, one should have in mind that, even though these wasted and residue crops have a larger yield, pre-treatment of this type of cellulose-containing material is still not economically feasible. Furthermore, other improvements may have to be achieved by modifying crops to ease the pre-treatment of cellulose-containing material. An Australian-based company has developed a kind of sugar cane that produces cellulose-containing material which can be processed without expensive treatments (Farmacule, 2006).

Figure 16. Forecasted global bioethanol production from wastes



(Source: Kim & Dale, 2004)

3.6.5. Area needed to move an automobile a kilometre

Table 23 provides the driving range value for ethanol flexible-fuel passenger cars. This table shows the area of crop needed to move a car one kilometre. The fuel type used is an E85 blend, and the crop yield values for corn and sugar cane are taken from Figure 14. From this table we can see that, in general, we would need one half of square metre crop to move an E85 car one kilometre.

Table 23. Area of crop needed to move a car 1 km using bioethanol

Type of car	Fuel Type	Engine size/cylinders	Km/l	Crop yield (l/ha) Corn/Sugar cane	Area of crop/Distance travelled (m^2/km)
Mid-size	E85	2.7L/6	*City:* 6.4 *Hwy:* 8.52	*Corn:* 3000	*City:* 0.52 *Hwy:* 0.39
				Sugar beet: 5000	*City:* 0.31 *Hwy:* 0.23
				Sugar cane: 6000	*City:* 0.26 *Hwy:* 0.20
Large	E85	4.6L/8	*City:* 5.1 *Hwy:* 7.7	*Corn:* 3000	*City:* 0.65 *Hwy:* 0.43
				Sugar Beet: 5000	*City:* 0.39 *Hwy:* 0.26
				Sugar cane: 6000	*City:* 0.33 *Hwy:* 0.22

(Source: DOE/EPA, 2006)

Summary: Land availability and land use are main issues of biofuels. Some of the factors that have to be considered in this context are the competition of biofuels with food production, urbanisation areas, nature development, and also the fact that yields of biofuels from energy crops depend on the geographical area of the world. The land availability studies estimate that biofuels production could replace around 10-30% of current gasoline consumption. However, economic and environmental feasibility is still unclear. Should a good solution be found to these outstanding issues, using wasted crops could abate world gasoline demand by 30%.

3.7. Summary of techno-economic uncertainties

3.7.1. Uncertainties of direct economic nature and the need for comprehensive models

There is currently a debate regarding whether the net energy return of producing biofuels is positive or negative. The controversy involves a considerable number of studies addressing the energy balance. For example, Pimentel & Patzek (2005) support the idea that no economic, environmental, or social improvement use can be achieved from biofuels use. They state that ethanol produced form corn, switch grass, and wood biomass requires *more* energy to produce than what is obtained. They also state the same for biodiesel obtained from soybeans and sunflower seeds. Finally, they argue that ethanol production subsidies only support huge profits for some large corporations. This paper created a lot of controversy because the study took into account more variables than previous studies.

Very recently, two studies have attempted to clarify the energy balance issue. The National Academy of Science of the United States published a comparable study (Hill et al., 2006) that took into account the same variables as Pimentel & Patzek (2005) but with updated data. *They found the assertion that ethanol from corn grain has a negative energy return to be false*. However, the *net energy gain for ethanol is relatively small* (~25%) *but very high for biodiesel from soybean* (~93%). Hill and co-workers found that for every litre equivalent of ethanol approximately $0.20 and $0.29 for biodiesel were subsidised by the US government. Also, this has caused disagreement between policy makers and can eventually end their support. For example, based on information from Pimentel and Patzek, Italian senators pointed out the inefficiency of biofuels (Stagnaro, 2006) in their debates.

The American Petroleum Institute (API, 2006a) has recently stressed that lack of quality control of unsaturated and saturated oils obtained from soybean can lead to deficient biodiesel causing problems with the engine, for example clogged filters, higher emissions, and ‘frozen’ diesel fuel. Ensuring quality control would have a direct impact on prices and has not been addressed by the scientific community when evaluating the energy, environmental and economic impacts of these biofuels.

The American Institute of Petroleum also complained about the negative effects of ethanol in gasoline when transported through pipelines. It was found that ethanol “drags” more water into gasoline, thus reducing its octane number. Many researches considered that alcohol could be blended at the refinery. However, alcohol is actually blended at fuel stations (API, 2006b), entailing additional costs. This is an important economic issue.

Summary: There are still many uncertainties concerning the net energy return of biofuels. Authors like Pimentel and Patzek argue that the energy balance is negative, while other researches state the contrary.

As stated in the beginning of Section 3, in view of all the conflicting data and conclusions, *there is an urgent need to develop a detailed environmental, economic and energy model, that, aside from manufacturing, considers all the elements of the associated supply chain, in order to keep track of the feasibility and the competitiveness of biofuels with varying input data. S*uch a model needs to be clear, updatable, robust, and – most important – able to reconcile many of the energy, economic, and environmental issues that are still unaddressed, including the synergistic effect of biorefineries. Only in this way, a clear competitive advantage or disadvantage could be assessed.

3.7.2. Assessment of some externalities, including social costs / benefits (e.g., possible impact on employment) for each pathway / modality

EU

An increment of biofuels use, obviously, will have direct and indirect employment effects. The European Renewable Energy Council (EREC, 2006) estimated that meeting the EU target for renewable energy for 2010 will result in a growth in net employment in the biofuels sector of 424,000 jobs compared to the year of 2000. An indirect effect could be the multiplier opportunities which could increase the direct effect. Contrary, jobs in the biofuel sector might replace other jobs, and the net employment effect could be much less. Impact assessments indicate that the above mentioned indirect effect on net employment could range between minus 40,000 to plus 15,000 jobs, depending on how wages and unemployment payments evolve with higher energy prices (BRAC, 2006).

Australia

Meeting a 350 Ml target by 2010 under current policy settings could involve investment in new ethanol plant capacity (grain and molasses based), probably in rural/regional Queensland and NSW, and biodiesel capacity, probably in South Australia and Victoria. Modelling suggests this could provide some 648 direct and indirect jobs regionally, although these would not be net gains to employment nationally (Biofuels Task Force, 2005).

United States

In 2004, the ethanol industry created 147,000 jobs in all sectors of the economy and provided $2,000,000 of tax revenue to all government levels. It has been projected that for every billion litres of ethanol, 2,600 to 5,280 positions would be created (DOEgenomes.org, 2006b).

Benefits for farmers and the role of subsides

Agricultural reforms are introducing a new aid program to encourage the production of crops for energy use. Farmers can take advantage of the aid offered for the production of energy crops.

An aid of €45 per hectare is available to farmers who produce energy crops in the EU. It will be applied on a maximum guaranteed area in the whole EU, of 1,500,000 hectares (Directorate-General for Agriculture and Rural Development of the European Commission, 2003). Farmers qualify to receive the aid if their production of energy crops is covered by a contract between the farmer and the appropriate processing industry. Where the processing occurs on the farm concerned, no contract is necessary. The farmer and processor do not have to be in the same Member State.

There are many questions concerning the benefits for farmers, for example how will pressures for increased production and reduced energy prices affect them? Would small and mid-sized growers fare any better in the energy crop economy than they have in a rapidly consolidating food economy that has driven so many off the land? A major biofuels expansion could spur large-scale industrial agriculture, which often relies heavily on petroleum-based fertilisers and pesticides and deploys heavy fuel-guzzling farm machinery. *Pressures for large-volume production and cheap energy might ultimately harm smaller farmers and the environment, unless there are explicit policies to protect both* (Cook, 2006).

Most IEA countries and the EU have complex agricultural policies that make it difficult to understand what impact increased biofuels production would have on crop prices, agricultural subsidies, and net social welfare. Subsidies to farmers to produce biofuels may, in some cases, help to offset other subsides – for example, in the US there are programs to assist farmers if crop prices fall below certain levels (IEA, 2004).

Agricultural subsides that are provided to "first world" farmers may have a direct, adverse effect on the ability of farmers in the world's poorest countries to compete on the global market.

Since a largest potential for biofuels is located in Asia, and generally in tropical countries, which tend to be the poorest ones, an international market reform has to be addressed so that the global demand of biofuels could be supplied via fair and competitive markets. One solution could be to reduce import taxes for biofuels, and to increase investment in the production of energy crops in poorer countries.

Summary: One major social and economic benefit of biofuels is the jobs that would be created in all the production sectors, tax revenues, and gains to farmers who receive subsidies. In addition, farmers with competitive high-volume production and environmental-friendly practices would benefit; however, small farmers could be harmed if their current practices are not improved or if fair market structures are not implemented.

4. Main Content of Legislation and Regulatory Environment for Biofuels, CTL and GTL

4.1. Brief comparison of government intervention

Table 24 reviews government intervention in key markets, followed by a detailed description.

Table 24. General issues concerning government intervention on key markets for biofuels

	Relying on tax exemptions?	Promoting public and industry procurement?	Promoting production in developing countries?	Supporting research and development?	Maintaining market access for imported biofuels?
EU	Yes	Yes	Yes	Yes	Yes
US	Yes	Yes	Yes	Yes	Yes, with internal production preferred
Japan	Yes	Yes	Yes	Yes	Yes
Australia	Yes	Yes	Not clear	Yes	Yes

4.1.1. United States

History

The National Energy Policy Development (NEPDG) Group's findings and recommendations that where done for the 2001 for the National Energy Policy (NEPDG, 2001) can be summarised as follows:

- Create and develop energy partnership programs to promote biofuels use among companies and consumers
- Improve legislation to extend tax credits for the use of renewable energy, and specifically continue with the ethanol excise tax exemption.

In 2004, the National Commission on Energy Policy stated that the ethanol market share in the United States is expected to increase as a result of the phase-out of the gasoline additive MTBE and the possible adoption of a national Renewable Fuels Standard (RFS) that would double renewable fuel production to 18.9 billion litres per year (0.3 million barrels per day) by 2012. The report states that legislative efforts to promote ethanol should be aimed at maximising benefits in terms of these national interests, as opposed to the less certain local air quality benefits that are the basis of current ethanol requirements.

2006 directives

The latest report from the National Commission on Energy Policy (2006) states the key questions concerning biofuels. For example, future ethanol plants would have to be built close to existing energy infrastructure, because transportation costs will force plants to be located near feedstock sources. Other questions involve concerns of communities that will be affected by living near biorefineries and changes that should be made concerning the Conservation Reserve Program to allow the cultivation of energy crops on some of these lands.

Mandates and incentives

There are new mandates and incentives to promote alternative fuels, perhaps the most important of these mandates is the new federal Renewable Fuels Standard (RFS) established by the Energy Policy Act 2005, which requires that at least 15.1 billion litres of renewable fuels be used in 2006, ramping up to at least 28.4 billion litres in 2012. Ethanol is expected to be the dominant biofuel in the United States for some time to come, although the increased use of biodiesel is also expected. To implement the RFS, EPA is developing rules that require fuel refineries, blenders, distributors, and importers to introduce or sell minimum volumes of ethanol and biodiesel into the transportation fuels market each year as required under the RFS. Starting in 2013 and each year thereafter, EPA is required to establish a new RFS, which – at a minimum – maintains the same volume of renewable fuels sold relative to total gasoline sold on a percentage basis in 2012 (National Commission on Energy Policy, 2006).

There are other incentives in the Energy Policy Act 2005 to promote the use of E85. These include tax credits for the installation of refuelling infrastructure, DOE grants for the advancement of hybrid flexible-fuel vehicles, and federal fleet requirements. At present, corn is the feedstock for nearly all commercially produced ethanol in the United States, although this supply is likely to be limited given competing demand for food and animal feed.

Funding R&D Efforts

Recognising that a dramatic expansion of domestic biofuels production will depend upon the commercialisation of technologies that can convert cellulose-containing (i.e., woody or fibrous) materials to ethanol, Congress included a number of provisions in EPAct05 to promote the development of a mature cellulose-based biomass ethanol industry. Provisions in EPAct05 that are specifically aimed at cellulose-based ethanol include programs to provide loan guarantees and grants for the construction of cellulose-based ethanol production facilities, research grants, and an advanced biofuels technology program. Up to 2013, cellulose-based ethanol qualifies for enhanced credit toward meeting the overall RFS requirement (National Commission on Energy Policy, 2006).

Addressing Land Issues

Land-use concerns, in particular, are likely to become extremely important in the event of a large-scale expansion of the biofuels industry. In its 2004 report, the National Commission on Energy Policy (2006) noted that to become economic on a large scale, energy-crop production would increasingly need to be integrated with existing agricultural and forestry production. Other concern is that ethanol facilities have not been completely free from local opposition and ethanol developers sometimes encounter public concerns, particularly related to odours emitted from the plants. If there is a significant increase in ethanol production and numerous new facilities are proposed for construction, public opposition may become a more common problem for ethanol producers.

Transportation

Transportation of ethanol to market is accomplished today by using rail cars and barges. It will be advantageous to locate production plants near rail hubs or major rivers with active barge operations. On the other hand, if the US biofuels industry expands to the point where it becomes economic to construct dedicated pipelines for carrying ethanol to market, a wider range of sites for new plants may become viable. In that case, proximity to new pipeline hubs would likely become an important consideration in locating new ethanol plants. The issue of capacity planning and plant location will have to be addressed through models, as done by Lavaja et al. (2006) for ethyl lactate.

4.1.2. Europe – The EC Directive on Biofuels 2003

Biofuels

In the EU, the most recent directive aims at a 2% market share goal for biofuels in 2005 and a 5.75% share in 2010 (ECC, 2003a). Member states are relying on tax exemptions (ECC, 2003b) and biofuel use obligations to meet the targets. However, the objective of a 2% market share was not accomplished and the 2010 goal is considered to be hard to accomplish. For these reasons, a review of the Biofuels Directive of 2003 implementation will be presented by the Commission by the end of 2006 and by the 10th of January 2007 a strategic energy review is going to be created. Finally (by March 2007) the EU heads of state will adopt an Action Plan on a common energy policy.

Among the measures that will be implemented are (ECC, 2006):[17]

- Stimulation of demand for biofuels encouraging legislation promoting them
- Examination of CO_2 emissions reductions due to the use of biofuels and limits on additives
- Encouraging sustainable crop-growing among EU and developing countries
- Setting up a group to study biofuels opportunities and monitoring industries to make sure there is no discrimination
- Expanding feedstock supplies through implementation of energy crop schemes in which benefits can be obtained for farmers (monetary help, tax incentives, etc.), and monitoring biofuels demand impact on food supply and prices
- Enhancing trade opportunities through market access conditions for importing countries giving preference to 3rd world countries as in the case of the ACP group (African, Caribbean and Pacific developing countries)
- Support development of developing countries through Biofuels Assistance Packages
- Support research and development to strengthen the competitiveness of the biofuel industry, giving high priority to the “biorefinery” concept and other relevant technology platforms.

Synfuels

Synfuels are not part of the renewable fuels agenda, except for biomass to liquids (BTL). Very recently, the Alliance for Synthetic Fuels in Europe (ASFE) was founded. The group is composed of DaimlerChrysler, Renault (including Samsung and Dacia), Royal Dutch Shell, Sasol-Chevron, and Volkswagen Group. ASFE members seek political and fiscal support from EU and national policy makers for the introduction and increased penetration of all synfuels, and more specifically to (ASFE, 2006):

- Include GTL as an alternative fuel that could help EU alternative fuel targets
- Push GTL to commercialisation

---

[17] The complete summary is included in the Annex II.

- Increase support, including R&D, for BTL production pathways and advanced engine technologies
- Promote BTL production as means of developing a new and sustainable business in the agricultural sector.

European directives and policies are closely followed by governments around the world, therefore they need to be understood well and taken into consideration.

4.1.3. Japan

Japan is considering alternative fuels. The primary force of the drive of the Government of Japan toward biofuels is its commitment under the Kyoto Protocol to reduce emissions. There are at least six feasibility studies under way that are analysing the prospects for biofuel production. However, the prospects for production and distribution of biofuels are limited by Japan’s shrinking and geographically limited agricultural sector. In order for biofuels to be adopted nationwide, Japan would need to import either the raw commodities or the biofuels. Indeed, Japan has begun imports of ethanol in 2001 from Brazil and other countries and is incorporating them into ETBE production (USDA FAS, 2006). In 2005, it imported 509 million litres, including roughly 359 million litres from Brazil. In 2005 the Brazilian Agriculture Ministry reported exports of ethanol to Japan were mainly for use in chemical products and alcoholic beverages. The widespread use of ethanol in Japan is somewhat influenced by the import and domestic tax structures (USDA FAS, 2006).

Japan’s first biomass plan, Biomass Nippon Strategy, was unveiled in 2002. The Strategy analysed biomass resources and set targets for the introduction of biomass with the goal of increasing utilisation of domestic food waste, wood and other materials. A 2005 review indicated that Japan was on track to meet its 2010 goals for food waste but not for wood waste. In addition, the entry into force of the Kyoto Protocol sent Japan into high gear to meet its commitment to reduce CO_2 emissions by 6% by 2010. Japan’s Biomass Strategy sets out to use 500,000 kl (oil basis) of biofuels for transportation, contributing to a 0.6% reduction in CO_2. The plan incorporated a 2003 decision to allow up to 3% blending of ethanol (E3) and for ETBE blending up to 8%. In practice, since January 2005 only six gasoline stations have offered E3 blended gasoline (USDA FAS, 2006).

Japan’s ethanol blend limit is low by US standards. Japan is taking a cautious approach to introducing a new technology with potential safety implications (USDA FAS, 2006).

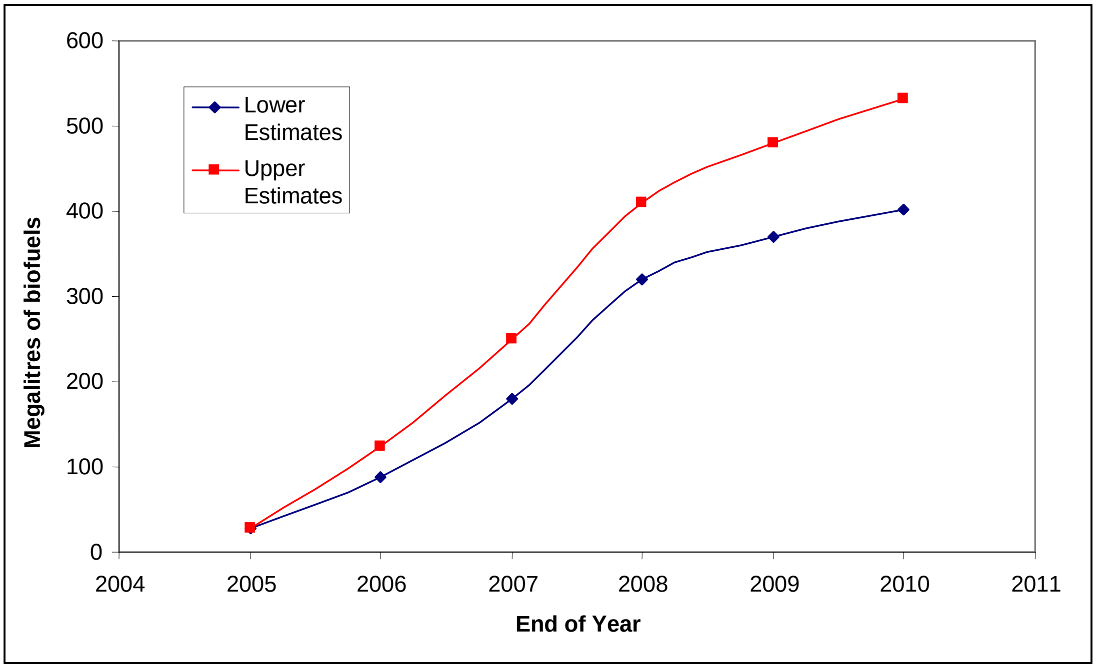
4.1.4. Australia – The Biofuels Action Plan

Australia enjoys an industry-government partnership that establishes a clear framework and foundation for a sustainable biofuels industry. The media release from the prime minister office states (verbatim): “The Australian Government has received Action Plans from the major oil companies, members of the Independent Petroleum Group, and the major retailers, which collectively provide achievable annual volumetric milestones to underpin progress towards the government’s target for 350 megalitres (Ml) of biofuels production by 2010 (Biofuels Taskforce, 2005).

The Action Plans clearly set out volumetric goals and business plans, including marketing and retail strategies, for both ethanol and biodiesel blended fuels. Based on the plans submitted, the 350 Ml target is achievable by 2010 (Biofuels Taskforce, 2005).

To achieve the 350 Ml target by 2010, production will increase annually from a base of 28 Ml in 2005 and will exceed the biofuels target of 350 ML in 2010, based on the aggregation of each company's projections (see Figure 17 for upper and lower production estimates). These estimates are predicated on continued improvements in consumer confidence, reliable and multi-source supplies of biofuels at competitive prices and the removal of market barriers (Biofuels Taskforce, 2005).

Figure 17. Industry projections up to 2010 for Australia based on companies' action plans



(Source: Biofuels Task Force, 2005)

The Australian Government will monitor and review progress towards these targets on a six-month basis. The industry players have committed to update their company action plans on an annual basis and regularly assess their progress against the targets set out in their action plans. Some highlights:

- British Petroleum (BP) supplies E10 in many parts of Queensland including Brisbane, and has opened three sites in Canberra to provide E10 to that market and to service the government fleet. BP will be commissioning an E10 blend plant early in 2006 in Mackay
- Caltex has sites selling E10 in Far North Queensland, south-east Queensland and northern New South Wales. Caltex also supplies B5 and B20 blends in New South Wales and South Australia, including a trial of B5 at three NSW service stations
- Shell markets Shell Optimax Extreme, a super-high octane fuel formulated with 5 per cent ethanol, through Coles Express. Shell Optimax Extreme will be the official fuel of the V8 Supercars Championship for 2006

- Independents including United, Australian Farmers Fuel, and Neumann Petroleum sell biofuels across Australia. United sells Plus ULP and Boost 98, both formulated with ethanol at over 90 locations Australia-wide, Australian Farmers Fuel sells biofuels at more than 50 outlets across Australia, and Neumann Petroleum and Freedom Fuels each retail biofuels at 25 service stations.

This industry-government partnership is firmly committed to working together to create a sustainable biofuels industry in Australia. Australian Government initiatives to support these efforts include:

- A AUS$37.6 million Biofuels Capital Grants Program which will support new or expanded biofuels production capacity to reduce supply constraints;
- Commonwealth fleet use of E10, however a study is still required to assess the health benefits of E10 under Australian conditions;
- Increasing the number of fuel quality compliance inspections;
- Vehicle testing of E5 and E10 blends;
- Consideration of minor fuel specification changes to encourage development of biofuels." (Australian Prime Minister News Room, 2005).

4.1.5. Turkey

Turkey's strategic location makes it a natural "energy bridge" between the major oil producing areas in the Middle East and Caspian Sea regions on the one hand and consumer markets in Europe on the other. Another advantage is the relatively humid and warm climate which is appropriate for the cultivation of energy crops. Heavily populated towns are assumed to have biomass potential, which can be used for biofuels or electricity production. At present, almost all biomass energy is consumed in the household sector for the heating, cleaning and cooking needs of rural people (Demirbaş, 2001).

The growth of Turkey's energy sector has been accompanied by institutional reforms. One of the most important developments has been the liberalisation of all energy sectors, including electricity production and distribution, to private capital (both national and foreign). Since the share of imports in energy supply is expected to continue to grow (from 56% in 2000 to 62% in 2010), one of the most important objectives in energy policy is security of supply (Demirbaş, 2001).

The government has developed an energy policy aimed at diversifying energy sources and suppliers and attracting private capital. Special attention in the government's energy policy is paid to the development of international cooperation (Demirbaş, 2001).

Biomass, solar, geothermal and wind energy have a potential to supply a considerable portion of energy requirements in the coming years. Existing energy policies are:

- Planning energy research and development activities to meet Turkey's energy requirements of 156 million metric tons oil equivalent by 2010
- Meeting long-term demand using public and private capital, domestic and foreign
- Developing existing sources of energy, while speeding-up work on new sources

- Adding new and renewable sources as soon as possible to the process of meeting energy requirements
- Taking into consideration supply costs of energy imports
- Diversifying energy supplies and avoiding dependence on a single source or country
- Meeting energy demand as much as possible through indigenous resources
- Implementing measures for energy efficiency, preventing waste and minimising losses in energy production, transmission, distribution and consumption
- Protecting the environment and public health in the process of meeting energy requirements. Biomass can be used to meet a variety of energy needs, including generating electricity, heating homes, fuelling vehicles, and providing process heat for industrial facilities.

A main requirement in energy policy is to meet the fast-growing demand on time. Private sector capabilities have to be mobilised because of the limited financial capacity of the public sector, and also to increase competitiveness, efficiency, effectiveness, and profitability.

The bioenergy field in Turkey needs detailed experimental studies. At the moment, technology and the investments in biofuels are insufficient in Turkey (Haktanırlar Ulutaş, 2005).

4.1.6. Sugar policies: opportunity for change

Sugar producers in countries such as Japan, the European Union, and the United States receive more than double the world market price due to government-guaranteed prices, import controls, and production quotas. This protection has converted these countries from net importers to net exporters, and for this reason, lower-cost developing country producers have been deprived of export opportunities. More than half of the value of sugar production in OECD countries comes from government support or transfers from consumers – an average of $6.4 billion per year during 1999-2001 (Mitchell, 2004).

Sugar policies in the EU and in the US will face increasing internal pressures for reform as imports increase under international agreements. A better alternative would be to push for full liberalisation of the world sugar market to allow efficient producers to expand production and exports and consumers in protected markets to benefit from lower prices (Mitchell, 2004).

Summary: Government support is required to ensure market penetration and induce investment in alternative fuels. In the European Union, the United States, Japan and Australia, current policies for biofuels rely on tax exemptions, promoting public and industry procurement, supporting R&D, and maintaining market access for imported biofuels. Japan, EU and the US promote production in developing countries.

4.2. Brief Assessment of Rules Concerning the End-use of Fuels

4.2.1. Mandatory admixing requirements

- Japan's government targets 10% ethanol blends as the standard by 2008 (IEA, 2004)
- In Australia, the percentage of ethanol mixed with gasoline used to vary significantly from state to state, from 24% in ethanol-producing states to zero in others. In September 2002, the government announced changes to the policy, including the setting of a 10% limit to ethanol in blends (IEA, 2004)
- There is a considerable interest in the use of higher ethanol blends, particularly E85 (85% ethanol, 15% gasoline), and especially in the US The typical use of ethanol at the moment is in E10 blends, but some E85 is in use, and for biodiesel blends the content of biodiesel is typically less than 25%. The 1990 Clean Air Act Amendments and its oxygenated fuels program established a requirement that gasoline sold in "carbon monoxide (CO) non-attainment areas" must contain 2.7% oxygen, thus increasing the necessity of mixing ethanol in gasoline fuels (IEA, 2004)
- Germany, Austria and Sweden promote the use of 100% biodiesel in trucks with only minor fuel system modifications; in France, biodiesel is often blended at 5% in standard diesel fuel and at 30% in some fleet applications. In Italy, it is commonly blended at 5% in standard diesel fuel (Austrian Biofuels Institute, 2003). In the US, the most common use is for truck fleets, and the most common blend is B20 (Dieselnet.com, 2002).

4.2.2. Taxation

- Taxation of motor fuels in the United States is applied both by the federal government and by state governments. For ethanol, there is a federal tax credit of 1.4 cents per litre of 10% ethanol-blended gasoline, yielding effective tax credit of 13.7 cents per litre of ethanol. This credit applies to gasoline blends of 10%, 7.7% and 5.7% ethanol (IEA, 2004)

- In the EU, a trial scheme (under review in 2006) will provide extra aid of €45 per hectare of land (except set-aside land) used for energy crop production (i.e., crops used for biofuel or biomass power), capped at a total expenditure of €67.5 million, equal to 1.5 million hectares (IEA, 2004)

  Table 25 shows some of the EU country tax credits for ethanol by 2004.

Table 25. Current EU tax credits for ethanol

Country	Reduction in fuel excise duty (€/1000 l)
Finland	300
France	370
Germany	630
Italy	230
Spain	420
Sweden	520
UK	290

(Source: IEA, 2004)

- In 2001, the Australian government adopted a pro-ethanol policy, including eliminating the excise tax. A biofuel domestic production subsidy, equivalent to the excise duty (about $0.24 per litre) was implemented in 2002, resulting in an effective import duty at the value of the excise tax. In July 2003, the government announced an additional production subsidy for ethanol plants at the rate of $0.10 per litre, available until total domestic production capacity reaches 350 million litres or by end 2006 (IEA, 2004).

4.2.3. Vehicle engines

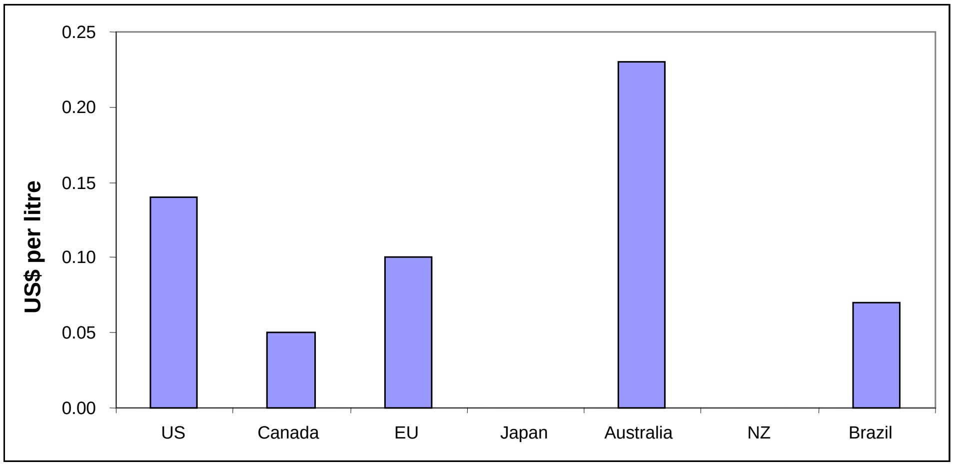
- There are ongoing tests in Japan regarding ethanol and vehicle engine compatibility. The Government has urged the automobile industry to produce models warranted for using gasoline containing 10% ethanol (IEA, 2004)
- There are some potential problems with operating conventional gasoline vehicles with an alcohol-gasoline blend. Alcohols tend to degrade some types of plastic, rubber and other components and accelerate corrosion of metals. These problems can be eliminated by using compatible materials (such as Teflon) to avoid degradation and by using stainless steel components (such as fuel filters) to avoid corrosion. The cost of making vehicles fully compatible with E10 is estimated to be a few dollars per vehicle (IEA, 2004). To produce vehicles capable of running on E85 may cost a few hundred dollars per vehicle. Moreover, very recently Ford announced the production of 250,000 E85 capable vehicles in an effort to help convert the Midwest states into a “bioethanol corridor”. Car makers are starting to take a key role to push forward biofuels to the market even further. In addition, car makers like Ford have started educational programs of the “novel” ethanol engines, so people can feel more comfortable to buy one and to fuel it with bioethanol (Green Car Congress, 2006)
- Blends of ethanol of 10% and below have no significant effect on engine performance and few mechanical or corrosion problems have been reported. This has been widely experienced in Brazil since 1994 (IEA, 2004).

4.2.4. Import-export restrictions

Production costs of biofuels in some developing countries with warm or tropical climate, like cane ethanol in Brazil, are much lower than grain ethanol in industrialised countries, such as the IEA countries. These cost differences create opportunities for biofuels trade that would substantially lower costs and increase supply to the industrialised countries; this would also encourage development of a new export industry in developing countries. Importing countries could invest in biofuels production in countries that can produce them more cheaply, if the benefits in terms of oil use and greenhouse gas emissions reductions are superior to what could be achieved domestically.

Historically, Germany has not strongly promoted fuel ethanol and has a high import duty of €19.2/ hectolitre for undenatured alcohol. In September 2002, Australia implemented a biofuel domestic production subsidy equivalent to an excise duty of about $0.24/litre, resulting in an effective import duty at the value of the excise tax. Brazil is currently negotiating with a number of countries (including China, Japan, South Korea, the US, and Mexico) that have expressed interest in buying Brazilian ethanol. While the US is one of the nearest and potentially biggest markets, agricultural subsidies and import restrictions frustrate Brazil’s export efforts. Figure 18 summarises ethanol import duties (IEA, 2004).

Figure 18. Ethanol import duties of some countries in 2004



(Source: IEA, 2004)

4.2.5. Trade policy to remove barriers to international biofuels trade

Due to the wide range of production costs and potential worldwide, there is a substantial potential benefit from international trade in biofuels. However, at present there is no comprehensive, nor is there even a substantial specific, trade regime applicable to biofuels. Biofuels are treated either as "other fuels" or as alcohol and are subject to general international trade rules under the World Trade Organisation (WTO). Biofuels are generally subject to customs duties and taxes without any particular limits.

The ethanol market in several developed countries is strongly protected by high tariffs, and OECD countries apply tariffs of up to $0.23 per litre for denatured ethanol. Some countries also apply additional duties to their tariffs, e.g., the US applies ad valorem tariffs of 2.5% for imports from most-favoured-nation (MFN) countries and 20% for imports from other countries. Japan applies ad valorem tariffs of 27% (MFN treatment). Given that ethanol produced in countries like Brazil appears to be on the order of $0.10 to $0.20 per litre cheaper to produce than in IEA countries, and that ocean transport costs are probably less than a penny per litre, duties on the order of $0.10 per litre or higher represent a significant barrier to trade. However, ethanol is included in a list of environmental products for which accelerated dismantling of trade barriers is sought, so there are some prospects for the eventual elimination of these tariffs (IEA, 2004).

Summary: Supportive policies from governments have been essential to the development of modern biofuels over the last years. Regions looking to develop domestic biofuels industries should be able to draw important lessons form the pioneers like Brazil. Among the successful policies that have been done for the production and use of biofuels are: (a) blending mandates; (b) tax incentives; (c) government purchasing policies; (d) support for biofuel-compatible infrastructure and technologies; (e) R&D&D (including crop research, conversion technology development, feedstock handling, etc.); (f) public education and outreach; (g) reduction of counterproductive subsidies; (h) investment risk reduction for next-generation facilities; and (i) gradual reduction of supports as the market matures, including the elimination of import restrictions.

5. Current Trends in R&D

5.1. Current trends for "first generation" and syngas-based fuels

Current research efforts in bioethanol involve new pre-treatment methods, energy integration in plants, genetically modified crops and bacteria, enzymatic developments, etc. Insertion of fermentation units to produce ethanol in biorefineries is likely to also increase savings, by managing by-products more efficiently and providing proper heat integration. Biodiesel efforts involve quality control issues regarding saturated and unsaturated oils, use of animal greases, genetically modified crops, modified algae, by-product choices, etc.

For synfuels, ongoing efforts are put in catalysts development for gasification and fuel production from syngas, new reactors designs, energy integration and CO_2 capture / sequestration.

Table 26. Other alternative fuels in the stage of research

Alternative	Description	Stage of research and/or development- Major roadblocks	Projected year of Market entrance
Hydrogen and fuel cells Feedstocks: Sodium borohydrate Fossil sources Biomethanol	Device that uses H_2 and O_2 to create electricity, with heat and water as emissions. Fuel cells have decades of use on spacecrafts and can provide auxiliary power for transportation	Novel materials for H_2 storage Membranes for separation, purification, and ion transport Catalyst design at nanoscale Solar H_2 production Bio-inspired materials and processes Reduce costs to make technology and production accessible for large scale use	The cost goal is of $0.53 to $0.79/gasoline litre equivalent (delivered, untaxed) for the 2015
MixAlco Feedstocks: Waste from landfills, corn stover, switch grass, proteins, etc.	Converts any biodegradable material into a mix of alcohols with higher energy. First biomass is treated with lime to increase digestibility of a mixed culture of micro-organisms. If used with prototype engine, a mileage of 235 mi/gal can be obtained	Not supported as biodiesel or bioethanol by the government and industry Ethanol can be obtained from this process but it is better obtained from other processes (fermentation, etc.)	It is thought to start to be commercially available by 2010 but can be introduced to market earlier if it receives the same support as bioethanol
BTL: Gasification route to synfuels Feedstock: switch grass, sweet sorghum, manure, waste crop straws, etc.	Breaking of solid carbohydrate materials into basic chemicals (CO, H_2, CO_2, H_2O, and CH_4) by first thermally depolymerising the biomass followed by carbon reforming reactions	Economic feasibility is being analysed Support is given for this technology that could enhance fuel land yield	It is thought to start to be commercially available by 2010 or sooner
Bio-oils: Pyrolysis and liquefaction	Pyrolysis converts biomass at temperatures around 500°C, in absence of O_2, to liquid (bio-oil), gaseous, and solid (charcoal) fractions	Bio-oil contains ~ 40wt% of O_2 and is corrosive and acidic. Crude bio-oil can be used for firing engines and turbines, or be upgraded in order to reduce O_2. To date, pyrolysis is less well developed than gasification	Market implementation is so far negligible. Pyrolysis now receives most attention as a pre-treatment step for long-distance transport of bio-oil that can be used in further conversion (e.g., oil gasification for syngas production)

Source of Hydrogen and Fuel Cells: DOE, 2006 and Rohm & Haas presentation at Rowan University, April 2006
Source of Hydrogen Cost Goal: DOE Hydrogen program cost goal, 2006
Source of MixAlco: Holtzapple, 2006
Source of Bio-oils: Faaij., 2006

5.2. Current trends for “second generation” biofuels and syngas-based fuels

Table 26 briefly outlines other options that have been considered to substitute oil based fuels. Part of these options is considered “second generation” biofuels.

Hydrogen and/or fuel cells have been supported but many technical issues have not been addressed yet, i.e., fuel cell robustness and/or source of hydrogen (See Annex I). The MixAlco Process (Holtzapple, 2001 & 2006) is a technology developed in the United States that has a very promising future, but has not attracted the attention of the government or investors yet. This mixture of alcohols has more energy output than other fuels and uses waste from landfills (waste has become a serious environmental problem). Annex II expands on the details of this technology. In turn, the feasibility of biomass to liquid technology from lingo-cellulose material has not been fully assessed. Finally, bio-oils have very little market implementation and little has been studied about its impact.

5.3. Current trends in “biorefineries” and the use of investment planning models

“Biorefinery” is new term that has been coined to refer to a complex of operations that uses biological feedstock (crops) and produces a variety of products. For example, aside from the well known ethanol, there are other possibilities: ethyl-lactate (a ‘green’ solvent), polylactic acid (a “green” plastic), and several other commodities (acetic, citric, fumaric, succinic, lactic, propionic acids, etc.) and its synergistic integration with biodiesel production, which adds other by-products (glycerol, xantham gum, etc.).

When planning biorefineries, the issue is to determine which processes and final products to pick, on what markets to sell them, at what prices, etc., in addition to the choices of raw materials. Defining location, initial and expansion capacities, as well as timing, is also needed. In view of the multiplicity of choices (discrete and continuous) decision making is nearly impossible without the use of an optimisation procedure. Such procedures have been developed since the 80s (Murphy et al., 1987; Eppen et al., 1989; Sahinidis et al., 1989; Berman and Ganz, 1994; Liu and Sahinidis, 1996; Ahmed and Sahinidis, 2000).

Work related to decisions surrounding GTL in Asian markets was performed by Aseeri and Bagajewicz (2004). This work considers competing technologies to process/deliver gas from source countries to consumer markets. Specifically, it considers the following options: LNG, CNG, pipelines or fuel production (through GTL), and delivery. The study determines markets to choose, technologies to use and source countries, as well as transportation means and capacity. One recent study (Lavaja et al., 2006), closely related to the area of bioethanol, determines multiple locations for plants, initial and expansion capacities (including their timing), chooses appropriate crops and optimises budgeting issues in the production of ethyl lactate, which is a “green” solvent. Finally, several of these models, including the aforementioned examples, handle uncertainty and manage financial risk using recently developed techniques (Barbaro and Bagajewicz, 2004), relying on the reduction of risk directly (probability of loss), downside risk (Eppen et al., 1989), or Value at Risk (VaR) (Jorion, 2000).

5.4. Current trends for genetically modified crops

The US Department of Energy's Office of Biological and Environmental Research is funding a $1.4 million project to determine ways to alter lignin in order to produce plants that yield more ethanol. Altering lignin's composition could improve access of enzymes, which would be able to more efficiently convert cellulose to sugars (Carbon Free News, 2006).

Another trend, which may take years to develop into marketable technologies, is to find a way to turn stalks and leaves, grasses and trees into sources of renewable biofuels. The major research has focused on corn modifications to increase yield per acre and dealing with crop fungus and pests (Melcer, 2006).

Brazilian scientists have been decoding the DNA of sugar cane which helps select varieties that are more resistant to drought and pests and yield more sugar content. Over the past 20 years, they have developed about 140 varieties of sugar crops which allow reducing production costs (Lunhow & Samor, 2006).

5.5. Current issues for synfuels

Studies of synthesis gas (syngas) production units aiming at the construction of GTL plants show that the key points in GTL involve scaling-up problems. Different companies are pursuing diverse technologies, especially in the syngas production steps (first step). Some, like BP and Petro SA are pursuing the traditional steam reforming method, which needs membranes to adjust hydrogen to CO ratios. Shell is pursuing the partial oxidation route which does not require catalysts, and ConocoPhillips is pursuing the catalytic partial oxidation route. Finally, Haldor Topsoe/Sasol and Syntroleum are developing the autothermal reforming route. The main difficulty is not energy costs and CO_2 emissions, but rather carbon and soot formation, as well as corrosion. CTL facilities are also subject to similar development issues.

Summary: Many efforts are underway to develop a second generation of biofuels. Among the most outstanding ones are hydrogen-powered fuel cells, alcohol mixtures obtained from wastes, BTL and pyrolysis routes. Many technologies are proposed to be used synergistically, using each other's by-products and energy surplus in complexes of units referred to as "biorefineries". Investment planning models to develop these (sometimes multi-site) enterprises are starting to be used. Genetically modified crops have been of major interest for many researches, since the development of these crops can be translated into higher yield of biofuels per cultivated area and less investment in agricultural resources like water, pesticides, fungicides, etc. Finally, research on scaling-up and improving GTL/CTL processes is underway, and large GTL facilities are under construction.

References

- Ahmed S., Sahinidis, N.V. (2000) Analytical Investigations of the Process Planning Problem. Computers & Chemical Engineering, 23(11-12), 1605-1621

- API – American Petroleum Institute, (2006a) Shipping Ethanol Through Pipelines, visited 13 August, 2006 http://api-ep.api.org/industry/index.cfm?objectid=54FD1A11-95FA-4B7C-ACE1D7C6F121FB1C&method=display_body&er=1&bitmask=002007003000000000

- API (2006b) Transporting Ethanol Presents Special Challenges. Energy Consumer 10-Apr-06. http://api-ec.api.org/policy/index.cfm?objectid=AED62CD2-4CA8-4419-8D50D449C1EB3454&method=display_body&er=1&bitmask=001001007000000000 vi: 5/Aug/06

- API (2006c), Backgrounder on Renewable Fuels for Diesel Engines. American Petroleum Institute, 29/June/06

- Aseeri A., Bagajewicz, M. (2004) New Measures and Procedures to Manage Financial Risk with Applications to the Planning of Gas Commercialisation in Asia. Computers and Chemical Engineering 28(12), 2791-2821

- ASFE – Alliance for Synthetic Fuels in Europe (2006) Synthetic Fuels: "Driving Towards Sustainable Mobility", Euractiv, http://www.euractiv.com visited on: 13/Aug/06

- Austrian Biofuels Institute (2003) Worldwide Review on Biodiesel Production, http://www.senternovem.nl/mmfiles/135528_tcm24-124334.pdf vi: 20/Aug/06

- Australian Prime Minister News Room (2005) Media ReleaseL Government Support for the Biofuels Industry, http://www.pm.gov.au/news/media_Releases/media_Release1580.html vi: 15/Jul/06

- Barbaro A. F., Bagajewicz., M. (2004) Managing Financial Risk in Planning under Uncertainty. AIChE Journal 50(5), 963-989

- Beer, T., Grant, T., Morgan, G., Lapszewicz, J., Anyon, P., Edwards, J., Nelson, P., Watson, H., Williams, D. (2006) Comparison of Transport Fuels. Final Report (EV45A/2/F3C) to the Australian Greenhouse Office on the Stage 2 Study of Life-cycle Emissions Analysis of Alternative Fuels for Heavy Vehicles. http://www.greenhouse.gov.au/transport/comparison/index.html vi: 26/Nov/06

- Berman O. and Ganz Z. (1994) The capacity expansion problem in the service industry. Computers & Operations Research 21, 557–572

- BRAC – Biofuels Research Advisory Council (2006) Biofuels in the European Union – A vision for 2030 and beyond. European Communities, p. 19

- Biofuels Taskforce – Australian Government (2005) Report of the Biofuels Taskforce to the Prime Minister, August 2005 www.pmc.gov.au/biofuels visited: 31/Jul/06

- Blottnitz H.v., Curran M. A. (2006) A review of assessments conducted on bioethanol as a transportation fuel from a net energy, greenhouse gas, and environmental life cycle perspective. Journal of Cleaner Production, in Press

- California Energy Commission (2006) Synthetic Diesel Fuel – Gas-to-Liquids (GTL) Fuel Fact Sheet. www.energy.ca.gov/afvs/synthetic_diesel.html vi: 15/Sep/06

- Carbon Free News (2006) New Biofuel source could take root, Carbon Free News, UK – Aug 25, 2006, www.carbonfree.co.uk/cf/news/wk35-0004.htm vi: 9/Sep/06

- Chemical & Engineering News (2006) Big companies invest in biodiesel. C&EN 84(21), p. 19
- Clark R., et al. (2002). "An evaluation of shell GTL Diesel – The environmental benefits", Shell Global Solutions Inc., 8th Diesel Engine Emissions Reduction Workshop, 25-29 August, San Diego CA
- Cook C.D. (2006) Biofuels: who benefits? Small growers or big business?, Organic Consumers Association, http://www.organicconsumers.org/ofgu/biofuel060418.cfm vi: 2/Sep/06
- da Silva, Luiz Inacio Lula. (2006) "Fuel for Thought". The Wall Street Journal (Eastern edition), New York, NY, 14 July, p. A12
- Demirbaş, A. (2001) Energy balance, energy sources, energy policy, future developments and energy investments in Turkey. Energy Conversion and Management 42, 1239-1258
- DFT – Department For Transport-UK (2004) International resource costs of biodiesel and bioethanol www.dft.gov.uk/stellent/groups/dft_roads/documents/pdf/dft_roads_pdf_024054.pdf vi: 15/Aug/06
- Dicks, A. L., et. al. (2004), "Fuel cells, hydrogen and energy supply in Australia", Journal of Power Sources 131 (2004) 1-12
- Dieselnet.com (2002) Synthetic Diesel Fuel. Ecopoint, Inc. http://www.dieselnet.com/tech/fuel_syn.html vi: 9/Sep/06
- Directorate-General for Agriculture and Rural Development of the European Commission (2003) The energy crops, http://europa.eu.int/comm/agriculture/index_en.htm visited on 02/Sep/06
- DOE Hydrogen program cost goal (2006) http://www1.eere.energy.gov/hydrogenandfuelcells/news_cost_goal.html
- DOE – Department of Energy (2006), Energy Efficiency and Renewable Energy, Hydrogen, Fuel Cells & Infrastructure Technologies Program http://www1.eere.energy.gov/hydrogenandfuelcells/ vi: 12/Aug/06
- DOE/EPA (2006); Fuel Economy Guide. DOE/EE-0309 www.fueleconomy.gov vi: 04/Aug06
- DOE/EPA (2006) Fuel Economy Guide 2007. DOE/EE-0314 www.fueleconomy.gov vi: 24/Nov/06
- DOEgenomes.org (2006a) http://genomics.energy.gov/ vi: 04/Aug/06
- DOEgenomes.org (2006b) Cellulosic ethanol: benefits and challenges, http://genomicsgtl.energy.gov/biofuels/benefits.shtml vi: 20/Aug/06
- ECC (2003a) DIRECTIVE 2003/30/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport. Official Journal of the European Union, 17/05/2003
- ECC (2003b) DIRECTIVE 2003/96/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity. Official Journal of the European Union, 31/10/2003, p. 283
- ECC (2006) COM(2006) – An EU Strategy for Biofuels. Communication from the Commission, 34final; Brussels, 8/02/2006
- Eetvelde, V.v., Antrop, M. (2004) Analysing structural and functional changes of traditional landscapes — two examples from Southern France. Landscape Urban Plann. 67, 79–95
- EEA – European Environmental Agency. (2006) How much bioenergy can Europe produce without harming the environment? European Environmental Agency: Copenhagen

- EIA – Energy Information Administration. World Energy Outlook 2006
- Environment New Services (2006), http://www.ens-newswire.com/ens/aug2006/2006-08-01-02.asp vi: 11/Sep/06
- EPA (2002) “A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions, Draft Technical Report, October.” Data covers biodiesel from different feedstocks
- Eppen G.D, et al. (1989) A Scenario Approach to Capacity Planning, Operation Research. 37, 517-527
- EREC (2006) Renewable Energy Scenario to 2040. European Renewable Energy Council, Brussels
- EUBIA (2006) Biofuels for Transport, www.eubia.org, vi: 21/Jul/06
- Faaij A. (2006). Bioenergy in Europe: changing technology choices. Energy Policy 34, 322-342
- Farmacule Bioindustries Pty Ltd. (2006) Genetic technology to produce cheaper ethanol from sugarcane.11/Apr www.farmacule.com vi: 15/Aug/06
- Goldemberg, J, (2000) World Energy Assessment, United Nations Development Programme, New York, USA, p. 135 – 171
- Goldemberg, J., Teixeira Coelho, S., Mário Nastari, P., Lucon, O. (2004) Ethanol learning curve – the Brazilian experience. Biomass and Bioenergy 26(3), 301-304
- Grassi, G. (1999) Modern Bioenergy in the European Union. Renewable Energy 16 (1999) 985-990
- Grassi, G. (2001) Biofuel for Transport. Latin America thematic network on Bioenergy. www.eubia.org vi: 29/Jul/06
- Grassi, G., et al. (2002) Clean energy for Brazil, 12th European Conference on Biomass for energy, Industry and Climate Protection 17-21 June, Amsterdam, The Nederlands
- Green C. (2000) Potential scale-related problems in estimating the costs of CO_2 mitigation policies. Climatic Change:44331–49
- Green Car Congress (2006) Ford Announces "Midwest Ethanol Corridor" and Hybrid Taxis in Chicago. 8-Feb-06 http://www.greencarcongress.com/2006/02/ford_announces_.html vi: 10-Sep-06
- HaktanIrlar Ulutas, B. (2005) Determination of the appropriate energy policy for Turkey, Energy 30(7) 1146-1161
- Hansen, A. C., et al. (2005) Ethanol – diesel fuel blends – a review, Bioresources Technology 96 (2005) 277-285
- Herrera , S. (2006) Bonkers about biofuels, Nature Biotechnology 24(7), p. 755-760
- Hill J., et al. (2006) Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels., PNAS 103(30) 11206–11210
- Holtzapple, M. (2001) Simultaneous saccharification and fermentation of lime treated biomass, Biotechnology Letters 23, 1327-1333
- Holtzapple, M. (2006) Presentation: Texas A&M University Distinguished Lecture 2006. http://engineering.tamu.edu/research/lectures/holtzapple_v3.html vi: 25/Jul/06

- IEA – International Energy Agency (2004), Biofuels for transport: an international perspective, Paris: IEA p. 25
- IEA – International Energy Agency (2004a) World Energy Outlook 2004. Paris: IEA, p. 169
- Institute of Transport Research, et al. (2003) Renewable fuels for cross border transportation, Final Report, June 2003
- Iowa Department of Agriculture and Land Stewardship (2003), Biodiesel Facts Sheet, The Office of Renewable Fuels & Coproducts. http://www.agriculture.state.ia.us/biodiesel.html vi: 26/Nov/06
- Jorion P. *Value at Risk. The New Benchmark for Managing Financial Risk*, 2nd Edition. McGraw Hill, New York, 2000
- Kadam K. L. (2001) Environmental benefits on a life cycle basis of using bagasse-derived ethanol as a gasoline oxygenate in Keith DW. (2001) Sinks, energy crops and land use: coherent climate policy demands and integrated analysis of biomass — an editorial comment. Climatic Change; 49, 1–10
- Kaltschmitt M, et al. (1997) Life cycle analysis of biofuels under different environmental aspects. Biomass and Bioenergy 1997; 12(2):121-134
- Kim, S., Dale, B.E. (2004b) Global potential bioethanol production from wasted crops and crop residues. Biomass and Bioenergy 26(4), 361-375
- Kristensen, L.S., Thenail, C., Kristensen, S.P., (2004). Landscape changes in agrarian landscapes in the 1990s: the interaction between farmers and the farmed landscape. A case study from Jutland, Denmark. J. Environ. Manage. 71, 231–244
- Lavaja J., et al. (2006) *Financial Risk Management for Investment Planning of New Commodities Considering Plant Location and Budgeting.* Industrial and Engineering Chemistry Research. To appear
- Li, Y-W. (2004) Clean Diesel Production from Coal Based Syngas via Fischer-Tropsch Synthesis: Technology Status and Demands in China. Plenary Lecture at International Pittsburgh Coal Conference ’04
- Liu M.L. and Sahinidis N.V., “Optimisation in Process Planning under Uncertainty”, Industrial Engineering and Chemistry Research, 35: 4154-4165, 1996
- Luhnow, D., Samor, G. (2006) As Brazil fills up on ethanol, it weans off energy imports, The Wall Street Journal, 16 January 2006. Seen on: http://yaleglobal.yale.edu/display.article?id=6817 visited on 5/sep/06
- MacDonald, et al. (2000) Agricultural abandonment in mountain areas of Europe: environmental consequences and policy response, *J. Environ. Manage.* 59, 47-69
- Macedo, I. d.C., Verde Leal, M.R.L., Acevedo Ramos da Silva, J.E. (2003) Greenhouse Gas (GHG) emissions in the production and use of ethanol in Brazil: Present Situation (2002). Secretariat of the Environment of the State of Sao Paulo
- Malan J., Aldrich J. (2006). An African parastatal’s view of Africa challenges and opportunities, Petro SA, Parow, Cape Town South Africa, March 9
- Marsh, G., Bates, J., Haydock, H., Hill, N., Clark, C., Freund, P., (2003) “Application Of CO_2 Removal to The Fischer-Tropsch Process To Produce Transport Fuel”, in “Proceedings of the Sixth International Conference on Greenhouse Gas Control Technologies (GHGT-6)” (Gale, J., et al., eds.), Pergamon Press, 2003, Vol. 1, 75-80
- Melcer R. (2006) Biofuels: scientists seek to unlock genetic, Checkbiotech.org (press release), Switzerland – Aug 25, 2006

- Minnesota Department of Agriculture (2002), Energy Balance/Life Cycle Inventory for Ethanol, Biodiesel and Petroleum Fuels. http://www.mda.state.mn.us/ethanol/balance.html vi: 8 August 2006

- Mitchell D. (2004), Sugar policies: opportunity for change, World Bank Policy Research Working Paper 3222, February 2004

- Mortished, C. (2006) Clean and green, but is biofuel a winner? The Times 07/Aug/06 www.timesonline.co.uk vi: 3/09/06

- Murphy F.H., Sen, S., Soyster A.L., "Electric utility expansion planning in the presence of existing capacity: a non-differentiable, convex programming approach", Computers & Operations Research, 14:19–31, 1987

- National Biodiesel Board (2006) Biodiesel Myths and Facts. http://www.biodiesel.org/resources/fuelfactsheets/Myths_Facts.pdf vi: 15-Aug-06

- National Commission on Energy Policy (2006), Siting Critical Energy Infrastructure – an overview of needs and challenges. A white paper prepared by the staff of the national commission on energy policy, June 2006

- Ondrey G. (2004) "Gas-To-Liquid projects get the green light", Chemical Engineering, 111(5), 23-27

- Perlack, R. D., et al. (2005) "Biomass as feedstock for a bioenergy and bioproducts industry: the technical feasibility of a billion-ton annual supply"; A joint study sponsored by: US Department of Energy, and the US Department of Agriculture; Available electronically at: http://www.osti.gov/bridge

- Pimentel, D., Patzek, T.W. (2005) Ethanol production using corn, switchgrass, and wood; biodiesel production using soybean and sunflower. Natural Resources Research 14, 65-75

- Puppan D. (2002) Environmental evaluation of biofuels. Periodica Polytechnical Social and Management Sciences 2002;10(1):95e116

- Reijnders, L., Huijbregts, M. A. J. (2006). Life cycle greenhouse gas emissions, fossil fuel demand and solar energy conversion efficiency in European bioethanol production for automotive purposes. Journal of Cleaner Production, 1-7

- Reinhardt G, Uihlein A. (2002) Bioethanol and ETBE versus other biofuels for transportation in Europe: an ecological comparison. In: The 114th international symposium on alcohol fuels (ISAF XIV). Phuket, Thailand

- Rentech, Inc. (2006). Rentech, Inc. and Peabody Energy Enter Into a Joint Development Agreement for Two Coal-to-Liquids Projects. Press Release, July 18

- Royal Dutch Shell plc (2005), Form 20-F, Annual Report 2005, The Netherlands

- Sahinidis N.V., Grossmann I.E., Fornari R.E., Chathrathi M., "Optimisation Model for Long Range Planning in the Chemical Industry", Computers and Chemical Engineering, 13: 1049-1063, 1989

- SASOL (2006) GTL Brochure – Reaching new energy frontiers through competitive GTL technology, June

- Schaberg P., (2005), "Future Fuels: Issues and Opportunities", SASOL, 11th Diesel Engine Emissions Reduction Conference, Chicago, August 21-25, 2005

- Schubert, C., (2006) Can biofuels finally take centre stage?, Nature Biotechnology, 24 (7) July 2006

- Shapouri, H., (2006) 23rd International sweetener symposium, http://www.sugaralliance.org/library/site/Shapouri-ETHANOLSFEEDSTOCKASAAug2006.pdf#search=%22shapouri%202006%22 vi: 20/Aug/06

- Sheehan J, et al. (2004) Energy and environmental aspects of using corn stover for fuel ethanol. Journal of Industrial Ecology; 7(4) 117-146

- Shell.com (2006). International Projects. http://www.shell.com/home/Framework?siteId=shellgasandpower-en&FC2=/shellgasandpower-en/html/iwgen/products_and_services/what_is_gtl/international_projects/zzz_lhn.html&FC3=/shellgasandpoweren/html/iwgen/products_and_services/what_is_gtl/international_projects/international_projects_100206.html, vi: 14/08/2006

- Shumaker, G.A., McKissick, J., Ferland, C., Doherty, B. (2003) A study on the feasibility of biodiesel production in Georgia. http://www.agecon.uga.edu/~caed/feasibilityrpts.htm vi: 8-Sep-06

- Slingerland, S., Geuns, L.v. (2005) Drivers for an International Biofuels Market. CIEP Future Seminar, Clingendael Institute, Discussion Paper 9/Dec/2005

- Spath P. L., Mann M. K. (2001) Life cycle assessment of hydrogen production via natural gas steam reforming, National Renewable Energy Laboratory, p. 23

- Stagnaro, C. (2006) Biofuels Delusions – The Saga of the Costly Fuels that Do Not Benefit the Environment. IBL Focus N. 18, 1-5

- Starrotor.com (2006) www.starrotor.com visited on: 15/Aug/06

- Steynberg, A. P., Nel, H. G., (2004) "Clean coal conversion options using Fischer-Tropsch technology", Fuel, 83(6), pp. 765-770

- Sweeney, G. (2006), Belief in RE: View from the top at Shell Renewables, Refocus 7(2), 60-63. (http://www.sciencedirect.com/science/article/B73D8-4JSGKRH-10/2/d405d80066699cecd3a920b518105542) visited on: 27/Aug/06

- Swenson D., (2006) Input-outrageous: the economic impacts of modern biofuels production, www.econ.iastate.edu/research/webpapers/paper_12644.pdf visited on: 10/Aug/06

- Tan R.R., Culuba A.B. (2002) A life cycle assessment of conventional and alternative fuels for road vehicles. In: InLCA. Seattle, Washington; 2002

- Texas A&M (2006) University Distinguished Lecture 2006 given by Dr. M. Holtzapple http://engineering.tamu.edu/research/lectures/holtzapple_v1.html vi: 9/02/06

- Toro C., F.A. (2004) Techno-Economic Assessment of Biofuel Production in the European Union – Working Thesis. Fraunhofer Institute for Systems and Innovation Research Karlsruhe, Deutschland

- UNFCCC – United Nations (2005) Convention Report on National GHG Inventory Data, http://unfccc.int/resource/docs/2005/sbi/eng/17.pdf. vi: 15/Aug/06

- UNFCCC – United Nations (2006), National Submittals 2006-2004 Greenhouse Gases Inventory, unfccc.int vi: 8/3/2004

- UNFCCC (2006a) Kyoto Protocol, http://unfccc.int/essential_background/kyoto_protocol/items/2830.php vi: 16/Aug/06

- UNFCCC (2006b) Status of ratification, last modified on 30 August 2006, http://unfccc.int/files/essential_background/kyoto_protocol/status_of_ratification/application/pdf/kpstats.pdf vi: 5/Aug/06 Page 5

- UNFCCC (2006c) – Kyoto Protocol Annex B, 1997 http://unfccc.int/essential_background/kyoto_protocol/items/3145.php

- USDA FAS (2003) Cost and Return Scenario. 20-Sep-2003 http://www.fas.usda.gov/pecad2/highlights/2003/09/biodiesel3/costreturnscenario.htm vi: 15-Aug-06

- USDA FAS (2006), Japan Biofuels production report, GAIN Report Number: JA6024, 5/26/2006

- Verburg, P.H., et al. (2006) Downscaling of land use change scenarios to assess the dynamics of European landscapes, *Agriculture Ecosystems and Environment* 114, 39–56

- Wang C.J., et. al. (2004) Effect of ethanol gasoline and unleaded gasoline on exhaust emissions of EFI vehicles with TWC, Huan Jing Ke Xue. 25(4), 113-116

- Williams, R.H., Larson, E.D. (2003) A comparison of direct and indirect liquefaction technologies for making fluid fuels from coal. Energy for Sustainable Development, vol. VII, no. 4, pp. 103-129

- World Watch Institute (2006) Biofuels for transportation – Global potential and implications for sustainable agriculture and energy in the 21st century, World Watch Institute, German Agency for Technical Cooperation (GTZ), June

- Wright, L. (2006), "Worldwide commercial development of bioenergy with a focus on energy crop-based projects", Biomass and Bioenergy, Vol. 30, Issues 8-9, Aug-Sep

- Yamashita, K., Barreto, L. (2003) Integrated energy systems for the 21st century: coal gasification for co-producing hydrogen, electricity and liquid fuels. IR-03-039. International Institute for Applied Systems Analysis, Laxenburg, Austria

Annex I. Hydrogen as an alternative fuel

Hydrogen economy and fuel cells

Hydrogen is a potential alternative fuel. It can be combusted directly in internal-combustion engines, or it can be used in fuel cells to produce electricity with high efficiency and no harmful emissions (just water and heat).

The current issues around the use of hydrogen include the following:

- Technical barriers for its production to make it competitive still exist
- Delivery and storage as well as fuel cell technologies for transportation are still being developed
- There are safety concerns (explosions). Codes and standards need to be developed, and
- There is still a need to validate and demonstrate hydrogen and fuel cells on a meaningful scale.

Fuel cells are more energy-efficient than combustion-based power generation technologies. Fuel cell plants can generate electricity at efficiencies of up to 60%, while conventional-based power plants typically generates electricity at efficiencies of 33 to 35 percent. If fuel cells are used to generate electricity and heat (co-generation), they can reach even better efficiencies of up to 85%. Vehicles using electric motors powered by hydrogen fuel cells may have an energy efficiency of 40-60%, while internal-combustion engines in today's automobiles convert less than 30% of the energy in gasoline into power (DOE, 2006).

How is hydrogen produced?

Hydrogen can be produced form practically any source containing hydrogen in its composition and by many means (from a feedstock of biomass, water, and natural gas by using as a source of processing energy coal, nuclear power, renewable energy like wind, solar, geothermal, and hydropower) and by a variety of process technologies. In essence, however, when biomass, biological wastes or natural gas are used, the process is a variant of the BTL/GTL processes. Therefore, this technology for hydrogen production is bound to compete for raw materials with biofuels and GTL/CTL. Conversely, producing hydrogen by electrolysis from water does not compete with BTL/GTL, but with other uses of electricity. Finally, unless nuclear or solar energy is used to produce electricity to subsequently split water, large CO_2 emissions are expected, unless carbon sequestration is considered (DOE, 2006).

How is hydrogen used as vehicle fuel?

For transportation purposes other than direct combustion of hydrogen in engines, a fuel cell is needed. A fuel cell is a device that uses hydrogen and oxygen to create electricity and this electricity is then in turn used to power an electric motor and move the vehicle. The amount of power produced depends on the fuel cell type, size, temperature of operation, and pressure at which the gases are supplied to the cell (DOE, 2006).

How is hydrogen stored?

Storage of hydrogen as a gas typically requires high-pressure tanks (5000-10,000 psi tank pressure). Storing enough hydrogen onboard a vehicle to achieve a reasonably long distance driving between refuelling is a major challenge because hydrogen can be very hazardous if overpressure results from the storage: this can produce rupture of the pressure vessel and a subsequent ignition and explosion. Another way to store hydrogen is to transform it into its liquid state, which requires cryogenic temperatures (around -252.8ºC if stored at atmospheric pressure), which is quite impractical. Finally, one alternative is storing hydrogen by using absorbents/adsorbents, or in solid state in the form of metal hydrides, all of which are non-validated technologies under development, especially when applied to transportation (DOE, 2006).

How can it be delivered once produced?

Today, hydrogen is transported from the point of production to the point of use via pipeline, over the road in cryogenic liquid trucks or in gaseous pressurised tube trailers. Approximately 700 miles of hydrogen pipelines are currently in operation in the US. These pipelines are located near petroleum refineries and chemical plants. This is currently the lowest-cost option for delivering large volumes of hydrogen. Expanding the hydrogen delivery system may be achieved by adapting part of the natural gas delivery infrastructure to accommodate hydrogen is an option (DOE, 2006).

Is it safe?

The physical and combustion properties of hydrogen give rise to hazards that must be considered when designing and operating a hydrogen system. Although hydrogen has been used safely in chemical and metallurgical applications, the food industry, and the space program for many years, there is still a major concern about its use, especially because of its wide flammability range, low ignition energy, and flame speed (DOE, 2006).

As hydrogen and fuel cells begin to play a greater role in meeting the energy needs of nations and the world, minimising the safety hazards related to the use of hydrogen as a fuel is essential. Work needs to be done to ensure practices and procedures that will ensure safety in operating, handling, and using hydrogen in vehicle fuel applications (DOE, 2006).

What is the hydrogen economy?

The hydrogen economy is the projection for a world hydrogen-energy based system in which hydrogen would be available for everyone through a clean and cost-effective production and with barely hazard potentials. The benefits of a hydrogen economy would help address concerns about energy security, global climate change, and air quality. *Hydrogen can help reduce GHG emissions only if the hydrogen is produced using renewable resources, nuclear power, or clean fossil technologies usually accompanied with carbon sequestration* (DOE, 2006).

Energy balance

The energy balance for the production of hydrogen depends on the production process. For example, a study of life cycle assessment of hydrogen production via natural gas steam reforming (Spath & Mann, 2001) shows that for every 0.66 MJ of hydrogen produced, 1 MJ of fossil energy must be consumed. This negative balance can be inverted by developing better and more efficient production processes, or by a major use of renewable sources like wind or solar energy.

The role of nuclear energy in the hydrogen economy

Traditionally, nuclear energy is transformed into electricity at relatively low costs. However, electricity cannot be stored efficiently. In order to solve this problem and for other reasons, hydrogen has been suggested to be the primary output of nuclear power plants. Between the most important reasons, hydrogen can store and carry otherwise “unstorable” energy and be ready to use. This can be done without risking electricity demand because electricity can be produced economically at many different scales using many different technologies. Despite these facts, social acceptance is still needed in some countries to widely use this technology.

Annex II. MixAlco

Dr. Mark Holtzapple at Texas A&M University developed the MixAlco Process which is a biological/chemical method. It converts any biodegradable material (e.g., urban wastes, such as municipal solid waste and sewage sludge, agricultural residues such as corn stover, sugarcane bagasse, cotton gin trash, manure) into useful chemicals, such as carboxylic acids (e.g., acetic, propionic, butyric acid), ketones (e.g., acetone, methyl ethyl ketone, diethyl ketone) and biofuels, such as a mixture of primary alcohols (e.g., ethanol, propanol, butanol) and/or a mixture of secondary alcohols (e.g., isopropanol, 2-butanol, 3-pentanol), using fermentation based on bacteria found in natural habitats such as the rumen of cattle and marine and terrestrial swamps, for approximately one year under anaerobic conditions, without the need of enzymes as in ethanol fermentation. Because of the many products that can be economically produced aside from fuels, the MixAlco process is the true embodiment of a biorefinery.

The MixAlco Process has been in development since 1991, moving from the laboratory scale (10 g/day) to the pilot scale (20 lb/day) in 1998. A small demonstration-scale plant (1 ton/day) is expected to be commissioned in 2007 and a 100 ton/day demonstration plant within the next two years.

Because the MixAlco Process uses a mixed culture of microorganisms, not needing any enzyme addition, the fermentation requires no sterility or aseptic conditions, making this front step in the process more economical than in more popular methods for the production of cellulose-based ethanol. These savings in the front end of the process, where volumes are large, allows flexibility for further chemical transformations after dewatering, where volumes are small.

The high energy content of the resulting alcohol mixture means that it can be used in more efficient engines that use a cycle similar to a jet turbine (Starrotor.com, 2006). As a result, more than 85 km can potentially be travelled with only one litre of this fuel (Holtzapple, 2006). Table 27, compares the energy contents of MixAlco to that of other fuels.

Table 27. Energy content per litre for various fuels compared to MixAlco

	Energy [MJ/L]
Gasoline	34.9
Mixed Alcohols Version 1	29.0
Mixed Alcohols Version 2	26.5
Ethanol	23.4

(Source: Holtzapple, 2006)

Annex III. Promotion of biofuels by the EU Commission

This appendix describes the seven policy axis under which are grouped the measures the Commission intends to take to promote the production and use of biofuels.

For stimulating demand for biofuels the Commission will

- bring forward a report in 2006 with a view to a possible revision of the Biofuels Directive. This report will *inter alia* address the issues of setting national targets for the market share of biofuels, using biofuel obligations and ensuring sustainable production
- encourage Member States to give favourable treatment to second-generation biofuels in biofuels obligations, and
- encourage the Council and European Parliament to give speedy approval to its recently adopted legislative proposal to promote public procurement of clean and efficient vehicles, including those using high blends of biofuels.

For capturing environmental benefits the Commission will

- examine how biofuel use can count towards the CO_2 emission reduction targets for car fleets
- explore and, where appropriate, propose measures to ensure optimal greenhouse gas benefits from biofuels
- work to ensure sustainability of biofuel feedstock cultivation in the EU and third countries
- examine the issues of limits on the content of ethanol, ether and other oxygenates in petrol; limits on the vapour content of petrol; and limits on the biodiesel content of diesel.

For developing the production and distribution of biofuels the Commission will

- encourage Member States and regions to take into account the benefits of biofuels and other bioenergy when preparing their national reference frameworks and operational plans under cohesion policy and rural development policy
- propose setting up a specific ad hoc group to consider biomass including biofuels opportunities within national rural development programmes, and
- ask the relevant industries to explain the technical justification for practices that act as barriers to the introduction of biofuels and monitor the behaviour of these industries to ensure that there is no discrimination against biofuels.

For expanding feedstock supplies the Commission will

- make sugar production for bioethanol eligible for both the non-food regime on set-aside land and the energy crop premium
- assess the opportunities for additional processing of cereals from existing intervention stocks into biofuels, to contribute to reducing the amount of cereals exported with refunds
- assess the implementation of the energy crop scheme by the end of 2006, and

- monitor the impact of biofuel demand on commodity and by-product prices, their availability for competing industries and the impact on food supply and prices, in the EU and in developing countries
- finance a campaign to inform farmers and forest holders about the properties of energy crops and the opportunities they offer
- bring forward a Forestry Action Plan, in which the energy use of forest material will play an important part
- review how animal by-products legislation could be amended in order to facilitate the authorisation and approval of alternative processes for the production of biofuels, and
- implement the mechanism proposed to clarify standards for secondary use of waste materials.

For enhancing trade opportunities the Commission will

- assess the advantages, disadvantages and legal implications of putting forward a proposal for separate nomenclature codes for biofuels
- maintain market access conditions for imported bioethanol that are no less favourable than those provided by the trade agreements currently in force, maintain in particular, a comparable level of preferential access for ACP countries and take into account the problem of preference erosion
- pursue a balanced approach in ongoing and future trade negotiations with ethanol-producing countries and regions – the EU will respect the interests of both domestic producers and EU trading partners, in the context of the rising demand for biofuels, and
- propose amendments to the *biodiesel standard* to facilitate the use of a wider range of vegetable oils for biodiesel production, and allow ethanol to replace methanol in biodiesel production.

For supporting developing countries the Commission will

- ensure that accompanying measures for Sugar Protocol countries affected by the EU sugar reform can be used to support the development of bioethanol production
- develop a coherent Biofuels Assistance Package that can be used in developing countries that have a potential for biofuels, and
- examine how the EU can best assist the development of national biofuel platforms and regional biofuel action plans that are environmentally and economically sustainable.

For supporting research and development the Commission will

- in the 7th Framework Programme continue its support for the development of biofuels and strengthening the competitiveness of the biofuel industry
- give a high priority to research into the “biorefinery” concept – finding valuable uses for all parts of the plant – and into second-generation biofuels
- continue to encourage the development of an industry-led “Biofuel technology platform” and mobilise other relevant technology platforms, and
- support the implementation of the Strategic Research Agendas prepared by these technology platforms.