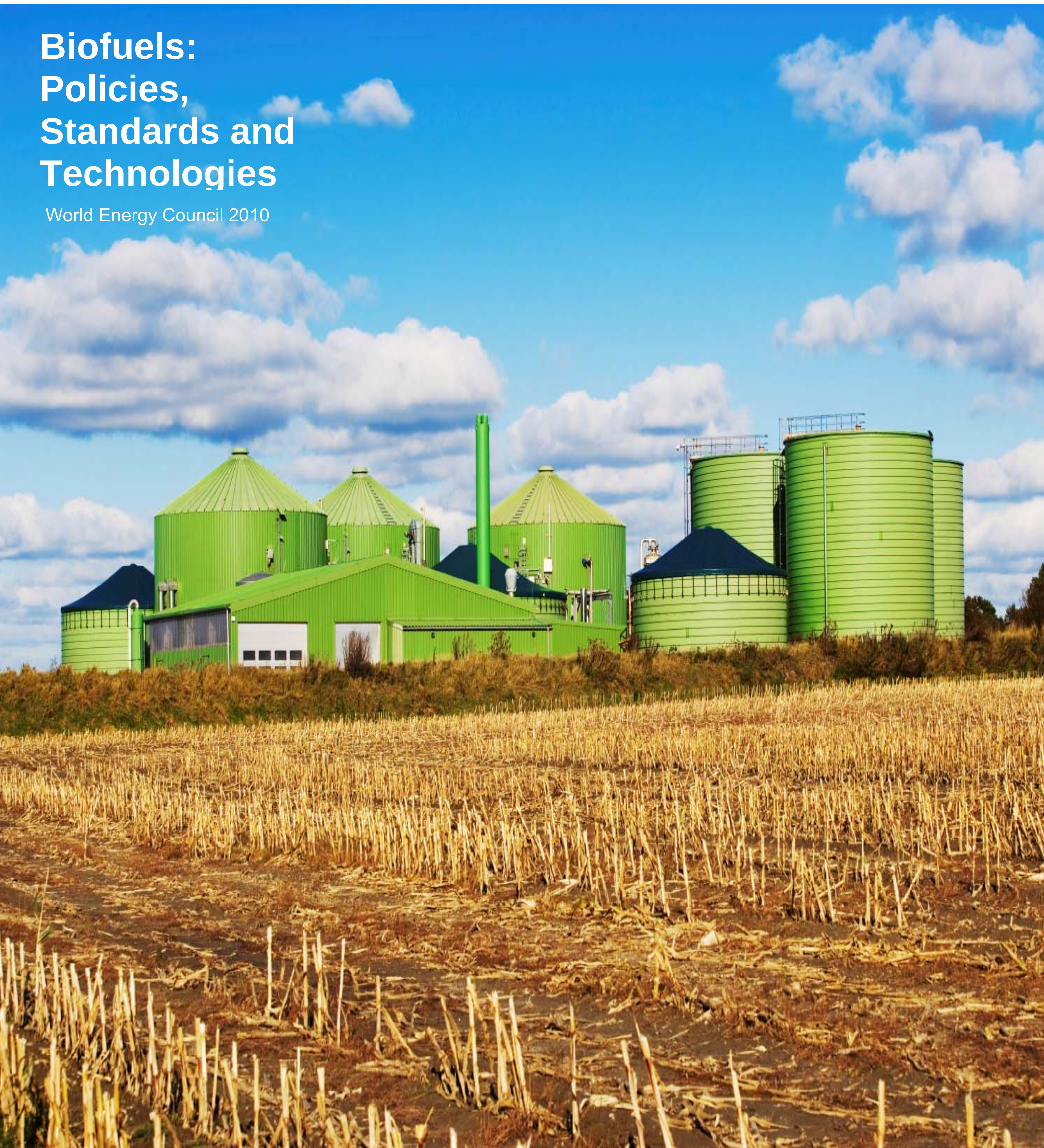
WORLD ENERGY COUNCIL
CONSEIL MONDIAL DE L'ÉNERGIE
For sustainable energy.

Biofuels: Policies, Standards and Technologies

World Energy Council 2010



Biofuels: Policies, Standards and Technologies

Biofuels: Policies, Standards and Technologies
World Energy Council 201010

Published 2010 by:

World Energy Council
Regency House 1-4 Warwick Street
London W1B 5LT United Kingdom

ISBN: 978 0 946121 03 8

Foreword

Skyrocketing prices of crude oil in the middle of the first decade of the 21st century accompanied by rising prices for food focused political and public attention on the role of biofuels. On the one hand, biofuels were considered as a potential automotive fuel with a bright future, on the other hand, biofuels were accused of competing with food production for land. The truth must lie somewhere in-between and is strongly dependent on the individual circumstance in different countries and regions. As food and energy are closely interconnected and often compete with each other for other resources, such as water, the World Energy Council - following numerous requests of its Member Committees - decided to undertake an independent assessment of biofuels policies, technologies and standards.

A Task Force on biofuels was set up by WEC in late 2008 and I was delighted to chair it over the past year or so. It was a challenging group effort which resulted in this report. From the beginning the Task Force established a certain criteria for its work which included issues related to the diversity of energy supply, standardisation of biofuels, trade policies, sustainability of biofuels production and use and other topical matters with the ultimate objective of promoting a better understanding of the basic fundamentals which will define the future of biofuels worldwide.

In many peoples' minds biofuels, ethanol in particular, are closely associated with Brazil which is today a leading producer not only of biofuels but also vehicles which run on biofuels. This is a unique combination and Brazil draws clear benefits from it. Ethanol in Brazil is produced commercially from sugar cane that has been grown in Brazil since its first settlements centuries ago and has the lowest production costs compared to other raw materials. It would be difficult to replicate these unique natural, traditional and technical factors elsewhere in the world. The report presents a global picture but focuses on the Americas. I would like to thank the members of the Task Force for their contributions to this effort, in particular my colleagues from Argentina, Analia Acosta and Raul Reimer, Ian Potter from Canada, Francesca Pigliapochi from Italy, Gerardo Bazan from Mexico, Bamidele Solomon from Nigeria, Ulf Svahn from Sweden and Richard Davis from the United States. The Task Force has also benefitted from the shared wisdom of Raffaello Garafalo and Luciana Tomozei from the European Biodiesel Board and Trevor Vyze from the International Standards Organisation. Finally, I would like to extend my appreciation to Elena Nekhaev and Catriona Nurse from the WEC London Secretariat for their support and guidance and to the Chairman of the WEC Brazilian Member Committee, Mr. Norberto de Franco Medeiros for my nomination as the Chair of the Task Force.

I sincerely hope that this report will become a succinct reference for both the decision-makers and the general public.

Sergio Fontes, Petrobras, Brazil

Task Force Membership

Chair:	Mr. Sergio Fontes, Petrobras, Brazil	
Members:		
Argentina	Ms. Analia Acosta	Repsol-YPF
	Mr. Raúl Reimer	Repsol-YPF
Canada	Mr. Ian Potter	Alberta Research Council
Colombia	Mr. Hans Ronald Moreno	ECOPETROL
Egypt	Mr. Abed Elmallahy	Egyptian Ministry of Petroleum
Italy	Mr. Franco Cotana	Centro di Ricerca sulle Biomasse
	Ms. Francesca Pigliapochi	ALPHA TRADING
Japan	Mr. Kenichiro Saitoh	Nippon Oil Corporation
Mexico	Mr. Gerardo Bazán	PEMEX
Nigeria	Prof. Bamidele Ogbe Solomon	National Biotech Development Agency
	Mrs. Rose Gidado	National Biotech Development Agency
	Mr. Austin Amaechi	Executive Reach NIGERIA
Swaziland	Mr. Henry Shongwe	Ministry of Natural Resources and Energy
Sweden	Mr. Ulf Svahn	Swedish Petroleum Institute
USA	Mr. Ron Wood	B&V Energy
	Mr. Richard Davis	Research Triangle Institute
International organisations:		
	Mr. Raffaelo Carafalo	EBB European Biodiesel Board
	Ms. Luciana Tomozei	EBB European Biodiesel Board
	Mr. Trevor Vyze	ISO International Standards Organisation
World Energy Council:	Ms. Elena Nekhaev	

CONTENTS

Foreword	**3**
Task Force Membership	**4**
Executive Summary	**7**
1. Introduction	**15**
2. Biofuels in the Global Energy Scene	**20**
3. Production and End-Use Technologies	**32**
4. Market, Financial Issues and Criteria	**54**
5. Standards, Policies and Regulation	**64**
6. Sustainability Criteria	**76**
7. Conclusions and Recommendations	**77**

Acronyms/Abbreviations

Annexes

Bibliography

References

Executive Summary

The use of biofuels is growing around the world and a debate between biofuels supporters and opponents is intensifying. Given the rapidly increasing demand for energy which is projected to double by mid 21st century, it is expected that biofuels will become an important part of the global energy mix and make a significant contribution to meeting energy demand. Drivers for a wide introduction of biofuels vary across the world and include a broad range of issues from land-use to energy security, to economics and environment. The main challenge for the future is to develop biofuels which do not compete with the food chain, which are sustainable and efficient both in terms of costs and energy, and for which the carbon footprint is a net gain. The study focuses primarily on biofuels for transportation and is divided into seven Chapters.

Background

The idea of using biofuels in an internal combustion engine dates back to 1929 when Rudolph Diesel first fired his newly invented diesel engine with raw vegetable (peanut) oil. However, Diesel and others discovered that fuelling a diesel engine with vegetable oils could reduce atomisation, lower heating value and worsen combustion and cause other long-term problems including pump wear and carbon/coke deposits.

In recent years, biofuels producers have achieved significant improvements in crop production and processing efficiencies and today the volume of biofuels produced in a specific planted area is several times higher than it used to be. Improved production methods and technologies are expected to increase efficiencies even further.

> Technology is a key factor to enhance both food and bio-energy production and increase the output without adverse economic and environmental implications.

One of the main goals of developing the biofuels sector is sustainability. The sustainability driver is based on the three pillars of economic, social and environmental sustainability. In economic terms, biofuels production has to be cost-effective and competitive. In social terms, biofuels development can create a massive new demand in the agricultural economy. As biofuels production is an agricultural process, the same elements and inputs contribute to its overall efficiency as for existing agricultural production systems.

International Standards

Many barriers that today constrain world trade in biofuels can be removed by introducing international specifications and standards. Not only must properties of final biofuels products be harmonised but also methodologies for measuring these properties. International bodies such as the International Standards Organisation (ISO) are the appropriate forum to discuss this subject with participation of all stakeholders.

ISO is currently working on developing certain biofuels standards, and the outcomes of this effort are eagerly awaited. The subsequent International Standards will help the broad development of biofuels worldwide.

Global Outlook for Biofuels

According to the latest official statistics, global production of biofuels reached a record level of over 34 Mtoe in 2007 accounting for 1.5% of total road related fuel consumption. Preliminary figures for 2008 suggest the total production increase to nearly 39 Mtoe. There are a number of reasons for the strong interest in biofuels which is currently spreading around the world and driving increasing production of biofuels. These reasons include the need to diversify supply sources, mitigate the impacts of crude oil price volatility, reductions in biofuels production costs and growing concerns about the global environment. In some regions, development policies also play an important role.

In terms of land use, the projected growth in biofuels production would lead to an increase in the arable land used for biofuels from about 1% of total available land today to approximately 2.5% in 2030.

Currently, two countries: Brazil and USA account for nearly 80% of global biofuels production. Both countries produce mainly bioethanol: USA from maize and Brazil from sugar cane. In the next few decades, global demand for transport fuel is expected to grow significantly – by up to 55% by 2030 compared to 2004. This will accelerate the growth in demand for biofuels, as they are expected to make an increasing contribution to meeting future energy needs of the mankind.

Despite the projected tripling of biofuels production from 20 Mtoe in 2005 to almost 60 Mtoe in 2015 and over 90 Mtoe in 2030, their share in the total road-transport fuel is not expected to surpass 4-5% by 2030. Biofuels production costs still remain comparatively high and substantial cost reductions are required for cost types to become commercially competitive.

Impact on food prices

The spreading concerns about the impact of increasing production of biofuels, possible competition for agricultural land and impact on the food prices require a holistic assessment since there is a number of various factors at play, including poor management of the agricultural sector during the last decades, unfavourable weather conditions, lack of investment in production capacity and infrastructure, distorted agricultural markets and the dismantling of support policies for domestic market in developed countries which all might have contributed to the recent increases in food prices all over the world.

The United Nations Food and Agriculture Organisation estimated in 2008 that biofuels accounted for approximately 10% of the recent food price increases around the world. In certain countries biofuels have had a more significant impact on food prices, however it was mainly because of national agricultural support programmes and protectionist measures rather than increased production of biofuels.

The key success factors for the future of biofuels will be gradual expansion in cultivated land and considerable increases in agricultural productivity. This will require a broad political commitment, including introduction of badly needed land reforms, better irrigation, use of fertilizers and further development of transport infrastructure.

The development of second-generation biofuels based on conversion of cellulosic resources, such as grasses, sawdust and fast growing trees from non-food sources that can help to limit the direct competition between food and biofuel that is associated with mostly first-generation biofuels should be a priority for sustainability of biofuels.

> The use of appropriate biotechnological tools and techniques for improving the plants yield, drought tolerance and multiplication offers the best solution in case of unforeseen adverse environmental conditions.

Land Use

A major debate continues around the world about biofuels production and its impact on traditional agriculture, i.e. the perceived competition for land and the risk of displacing production of human and animal food by biofuels.

Although land devoted to fuel production could reduce land available for food production, this is at present not a serious problem. In the longer term, lignocellulosics are likely to become the primary source of biofuels. It is important in each particular case to evaluate the sustainability of raw material production to ensure that biofuels are developed in areas that do not affect the use of the basic resources of agricultural ecosystems such us soil, water, air and biodiversity. In addition, taking into account the climate and geographical diversity, initiatives for the use of semi-arid soils and other marginal lands could be implemented for the benefit of supporting the development of rural populations in poor regions.

Analysis of areas today used for conventional crops production which are planned to be converted into biofuels producing areas is an important starting point for the evaluation.

> Generally, in many countries, the land used today for agriculture and biofuels production accounts for a small share of the total arable land.

Large-scale production of biofuels could increase the price of agricultural commodities. This would benefit farmers, but might increase food prices. Farmers could also produce their own fuels. The expected continued growth in the use of biofuels would increase global demand for agricultural products and result in the creation of new jobs in harvesting, processing, distribution, etc. A biofuels industry that is local and where farmers produce fuel for their own use would produce direct and multiple benefits to a rural community. Soil productivity has also been increasing all the time, due to better chemical fertilisers, physical fertility and more efficient water economy.

Agricultural practices that are environmentally sustainable, socially accepted and that promote efficient use of energy should be supported. All possible energy crops in each region should be assessed, including the second generation biofuels crops.

Geography and logistics

A general assessment of opportunities for biofuels production should include basic information such as location, associated transport and relevant infrastructure logistics. Some countries have their production base far from the main consumption centres and ports, in other countries it is the opposite. The origin of the crops or vegetable oils used for biofuels production is another aspect. Are they produced in the country or coming from other regions of the world?

For instance, in Argentina the raw material is produced in an area located 500 km from the biofuels processing plants but these plants, on the other hand, are located close to the ports and this is an unusual and beneficial situation. Biofuels production shall not rely on raw material coming from areas such as:

- Forests where there has not been significant human interference or where the last human intervention was long ago and where the natural species and processes have re-established themselves.
- Areas designated for nature protection purposes, unless evidence is provided that the production of biofuels does not interfere with those purposes.
- Forests and rainforests, unless they are managed using sustainable practices.
- Wetlands, i.e. land that is covered with or saturated by water permanently or for a significant part of the year, including peat land.
- Permanent grassland, i.e. rangelands and pasture land which have been under grassland vegetation and pasture use for at least 20 years and are not classified as forest.

Biofuels for Transportation

In the past few years there have been important advances in the field of alternative transportation fuels, primarily bioethanol and biodiesel. Only biodiesel and bioethanol are considered in this report due to their similar inherent properties compared to fossil-based fuels, especially auto-ignitibility. There is a longer-term potential for other biofuels such as biobutanol and biogas but little research effort has been seen in either regular or small engines.

Bioethanol is an alcohol, made by fermenting any biomass with a high content of carbohydrates through a process similar to beer brewing. Today, bioethanol is made from starches and sugars. In the future, cellulose and hemicellulose fibrous material will be used.

Biodiesel is made by combining alcohol (usually bioethanol) with vegetable oil, animal fat, or recycled cooking grease. These materials contain triglycerides and other components depending on type. Some of the feedstocks are palm oil, coconut oil, canola oil, corn oil, cottonseed oil, flex oil, soy oil, peanut oil, sunflower oil, rapeseed oil and algae. It can be used as an additive to reduce vehicle emissions or in its pure form as a renewable alternative fuel for diesel engines. In the near future, agricultural residues such as corn stover (the stalks, leaves, and husks of the plant) and wheat straw will also be used.

Fuel blends

Flexible-fuel vehicles (FFVs) can operate on any blend of bioethanol with gasoline up to 100% (E100). About seven million FFVs are currently used in the USA running on fuel with 85% bioethanol (E85). US auto companies have committed to manufacturer a larger number of FFVs, in a wide variety of models, to be available at prices competitive with conventional vehicles.

Not all diesel engine manufacturers however cover biodiesel use in their warranties. Biodiesel contains about 8% less energy per gallon than petroleum diesel.

Algae biodiesel

While algae biodiesel has the same characteristics as conventional fuel, the production process can be also used to capture CO_2 from power stations and other industrial plants (synergy of coal and algae).

Moreover algae biodiesel production can be combined with wastewater treatment and nutrient recycling, where polluted water (cleaned by algae) acts as a nutrient in their growth. But most importantly is that today algae biodiesel jet fuel represents the best potential answer for the sustainability of the aviation industry.

Issues related to Engines and Engine/Fuel Interface

Combustion characteristics of biofuels are different from those of regular fuels due to:

- differences in fuel flow,
- physical phase change,
- fuel atomization to chemical reaction, and
- heat exchange.

In addition to combustion issues, replacing fossil-based fuels with biofuels can lead to other concerns about engine performance, durability and fuel storage.

> The effects of replacing fossil-based fuels with biofuels depends on the inherent properties of the fuels and engine operating principles.

Technology Outlook for Biofuels

The recent developments in biofuels suggest that the rapid growth of biofuels use could continue for decades.

The potential for biofuels is particularly large in tropical countries, where high crop yields and lower costs for land and labour provide an economic advantage. It has been estimated that worldwide sugar cane production could be expanded so that crop alone could displace about 10 percent of gasoline use worldwide.

Biofuels Investment and Climate Change Regulations

Calls for global carbon regulations are growing. The Conference of the Parties 15 (COP15) held in Copenhagen in December 2009 was expected to reach a global far-reaching agreement to replace the Kyoto Protocol. This did not happen, although certain progress has been achieved on a number of points.

The Life Cycle Assessment (LCA) of the production of biofuels for energy applications or other end uses represents the tool most widely used for the GHG balance accounting.

Further, the debate on climate change is likely to produce regulations world-wide that will encourage and/or subsidise biofuel investments. To help overcome the risk of oil price volatility undermining investment in biofuels, regulators will need to enact particular policies to encourage investment into biofuels.

In general, as an alternative to oil, biofuels are not a safe investment today. As a potential help to climate change regulation, biofuels look like a good investment.

Technical Standardisation

Although major refiners like ConocoPhillips, British Petroleum/BP and others blend currently biofuels into transportation fuels like gasoline and diesel, this is not supported by sufficient technical standards which would allow and facilitate robust growth of biofuels on a global scale. Large, well-established refiners have the wherewithal to blend different source types into current transport fuels, but it typically requires new additions to traditional petroleum refineries that are expensive.

> Establishing biofuel technical standards would, over the long run, help reduce capital expenditures for large and small refiners, benefit new participants in the refining business, and help capital markets develop more specific products for syndicating debt for biofuel refining.

The application of certification schemes requires careful consideration of all factors involved. Early in the conception and the development stage, it is crucial to develop or to follow sound sustainability principles and criteria. Certification work is often criticised for lacking substance and structure and the following main issues have been identified:

- scope inconsistencies
- implementation inconsistencies
- market failures
- costs barriers
- trade limitations.

> Finally, the market players will determine the relevance of different standards. They will decide upon their individual needs (imports/exports into/from different countries, marketing purposes, costs etc.).

Conclusions and Recommendations

The world´s transport system is based on one single fuel - oil and today there does not seem to be any realistic alternative to oil. Demand for oil is expected to grow for decades to come, along with the overall demand for energy. Biofuels can help meet this demand, and even if they will not replace oil, they should be regarded as an integral part of the energy mix.

Supportive government policies have been essential to the development of modern biofuels. Countries seeking to develop domestic biofuel industries will be able to draw important lessons—both positive and negative—from the industry leaders, in particular Brazil, the United States and the European Union.

Biofuel policies should focus on market development and facilitate sustainable international biofuel trade. Free movement of biofuels around the world should be coupled with social and environmental standards and a credible system to certify compliance.

Tax incentives have been used effectively in Brazil, Germany, the United States and other countries to spur biofuel production and reduce biofuel prices at the pump. The enormous purchasing power of governments has been used successfully in a number of countries to expand the market for various products.

Consumer demand could be a powerful driver of the renewable fuels market. Strategies to increase the public's awareness about biofuels include various forms of public education, such as formal awareness campaigns, public announcements, university research, etc.

If biofuels continue their rapid growth around the globe, the impact on the agricultural sector can be significant. Increased jobs and economic development for rural areas in both industrialised and developing countries is one possibility, if governments put the appropriate policies in place and enforce them. The more involved farmers are in the production, processing, and use of biofuels, the more likely they are to benefit from them.

In regions where access to modern forms of energy is limited or absent, government and development agency support for small-scale biofuel production can help provide clean, accessible energy that is vital for rural development and poverty alleviation.

While it is recognised that biofuels have the capacity to reduce greenhouse gas emissions compared to fossil fuels, their production and use are not entirely without environmental implications. Depending on the crop type and other factors, carbon emissions are not always lower than for traditional fuels.

Biofuels can play a significant role in the context of a broader transformation of the transportation sector but alone they will not solve all of the world's transportation-related energy problems.

To achieve their full potential in providing security of supply, environmental and social benefits, biofuels need to represent an increasing share of total transport fuel compared to oil.

1. Governments should pursue efforts that lead to diversification of transport fuel sources to improve economic, energy and environmental security.

2. Agricultural policies should balance the need for food and water supplies with biofuels production.

3. When performing analysis of fuel source and type, a cradle-to-grave LCA is necessary for understanding of economic, energy and environmental impacts using a common, objective and transparent methodology.

4. Governments should conduct research to gain a better understanding of impacts of biofuels production and use on public health and local environment, as for other energy sources.

5. Governments and industry should invest in biofuels research and development to stimulate breakthrough technologies and share best practices and technologies for biofuels production and use.

6. Governments should pursue policies to encourage private sector investment into commercial scale production of biofuels – for proven technologies, including incentives for scaling-up technology from pilot to demonstration to commercial scale.

7. Each country should strive to develop open and free markets for biofuels, although grandfathering subsidies, tariffs and other tools might be needed until domestic markets have been established.

8. All agricultural policies and strategies are based on local, national or in some cases regional circumstances and they include the mix of environmental (land, water, climate), social (population, education) and economic (infrastructure, governance) factors. It is therefore impossible to develop “one-size-fits-all” policies for biofuels production.

9. Identifying the right place of biofuel production in the agricultural economy, including choices of the actual types (diesel from vegetable oil, ethanol from sugar or starch crops, solid biofuels from wood or grass sources) is a significant policy challenge.

10. While it is recognised that biofuels have the capacity to reduce greenhouse gas emissions compared to fossil fuels, their production and use are not entirely without environmental implications. Depending on the crop type and other factors, carbon emissions are not always lower than for traditional fuels.

1. Introduction

The use of biofuels is growing around the world and a debate between biofuels supporters and opponents is intensifying.

Responding to the interest of its members in this topic, the World Energy Council (WEC) convened a Task Force to examine the biofuels markets and identify the main production technologies in use today and in the future and the main barriers to an accelerated development and deployment of biofuels. The objective was to establish a set of recommendations for policy and decision-makers around the world to enhance understanding of biofuels. This report was produced from contributions of the WEC Task Force members from several countries. Each member had to cover a certain topic and all contributions were reviewed and agreed in the Task Force meetings.

The study focuses primarily on biofuels for transportation and is divided into seven Chapters:

Chapter 1 introduces general concepts and basic information about biofuels, including international standardisation, classification and certification issues and lays down the guiding principles adopted by the Task Force.

Chapter 2 looks into the future of biofuels, including land use and impacts on food prices, and presents brief case studies from eight countries.

Chapter 3 summarises information about the various aspects defining development of biofuels: geography, feedstocks, production and end-use technologies, issues related to engine/fuel interface, energy efficiency and a technology outlook for near and longer term.

Chapter 4 addresses markets, financial issues and criteria, petroleum price volatility, vegetable oil market dynamics, supply and demand fundamentals.

Chapter 5 reviews standardisation, general policies and regulations, in particular the examples of EU and Brazil.

Chapter 6 discusses sustainability principles and criteria, including Life Cycle Assessment, economic and environmental aspects.

Chapter 7 summarises the main messages and presents conclusions and recommendations.

It was recognised that in each country, biofuels were facing specific issues, e.g. climate, economic or supply security. It was agreed that the Task Force would not conduct specific case studies of Life Cycle Analysis (LCA), but would highlight the importance of LCA and formulate recommendations for further discussions.

The Task Force would focus on the most developed biofuels markets in North and South America to identify the drivers and success factors for a large-scale production and use of biofuels and development of new and efficient technologies.

Technology is a key factor to enhance both food and bio-energy production and increase the output without adverse economic and environmental implications.

Intensive collaboration with other international organisations active in this area was established, in particular, with International Standards Organisation (ISO) and the European Biodiesel Board (EBB).

Background

The idea of using biofuels in an internal combustion engine dates back to 1929 when Rudolph Diesel first fired his newly invented diesel engine with raw vegetable (peanut) oil. However, Diesel and others discovered that fuelling a diesel engine with vegetable oils could reduce atomisation, lower heating value and worsen combustion and cause other long-term problems including pump wear and carbon/coke deposits.

The effects of replacing fossil-based fuels with biofuels depend on the inherent properties of the fuels and engine operating principles. The first large-scale use of biofuels began in Brazil where bioethanol was initially mixed with gasoline. At that time, the main driver for biofuels development was not the replacement of fossil fuels but the reduction of imbalances between production and demand for sugar in the international markets. Brazil was a huge sugar producer and exporter and the price volatility of sugar caused severe difficulties in the country's economy.

The oil markets in the late sixties and early seventies consolidated the motivation to develop biofuels as a possible replacement for fossil fuels, especially in countries that were heavy crude oil importers like Brazil. Following oil crises, a number of countries began to develop and implement biofuels programmes, but these programmes lacked consistency and largely followed the crude oil prices.

In recent years, biofuels producers have achieved significant improvements in crop production and processing and today the volume of biofuels produced in a specific planted area is several times higher than it used to be. Improved production methods and technologies are expected to increase efficiencies even further.

In terms of the environmental impact, all biofuels are not the same and not always the most secure or cheapest way to reduce greenhouse gas (GHG) emissions, but taking into account that over 20% of all anthropogenic GHG emissions originate in transport and their share is growing rapidly, biofuels provide an attractive way of reducing emissions fairly quickly.

Security of supply has also become more important, given the increasing price volatility of crude oil. The uncertainty about the availability and the price of crude oil has focused attention on alternative transport fuels. One of the most relevant alternatives is biofuels.

One of the main goals of developing the biofuels sector is sustainability. The sustainability driver is based on the three pillars of economic, social and environmental sustainability. In economic terms, biofuels production has to be cost-effective and competitive. In social terms, biofuels development can create a massive new demand in the agricultural economy.

Sustainability criteria also demonstrates, among other aspects, how different forms of energy perform in terms of energy efficiency and environmental impacts. As biofuels production is an agricultural process, the same elements and inputs contribute to its overall efficiency as for existing agricultural production systems.

It is a well-known fact that different types of biofuels as well as different production technologies for the same biofuel can have very different energy efficiencies. When deciding which type of biofuel to grow and where, energy efficiency must be taken into consideration and weighed against GHG savings and other criteria.

When the harvested biomass is entering the actual biofuel production process, there are further decisions to be made, as different technological options perform differently in terms of energy use. Given a relatively limited availability of biomass, energy efficiency assessment of the entire biofuel cycle should be an essential part of the overall assessment of different alternatives.

Intensive agricultural systems based on the most advanced technologies and knowledge management, use less inputs per unit production than many other systems. The challenge addressed by the science-based agricultural industry is to maximize productivity while reducing the use of land, water and chemical inputs. The key to that goal is held by the dissemination of the latest technological advances in the life sciences worldwide.

Identifying the right place of biofuel production in the agricultural economy, including choices of the actual types (diesel from vegetable oil, ethanol from sugar or starch crops, solid biofuels from wood or grass sources) is a significant policy challenge.

All agricultural policies and strategies are based on local, national or in some cases regional circumstances and they include the mix of environmental (land, water, climate), social (population, education) and economic (costs, infrastructure, governance) factors. It is therefore impossible to develop “one-size-fits-all” policies for biofuels.

The criteria for decision making may be general, based on the three pillars of sustainability, but the relative weight given to economic, social and environmental aspects should be a matter for local decision making. For example, in areas of exceptional biodiversity, the weight of environmental considerations will likely to be different from that applied in areas with dense and poor rural populations.

Subsidies for biofuels feedstock can also distort markets. They may contribute to inefficient allocation of resources, and thus lead to distortion of food markets.

Another key issue is compatibility. Biofuels need to be compatible with current vehicles and transport logistics. This means that a fuel needs to meet current fuel specifications and can be blended into current fuel or use the same logistics. Fuel properties also need to be sufficient to be compatible with future engine designs.

International Standards

Many barriers that today constrain world trade in biofuels can be removed by introducing international specifications and standards. Not only must properties of final biofuels products be harmonised but also methodologies for measuring these properties. International bodies such as the International Standards Organisation (ISO) are the appropriate forum to discuss this subject with participation of all stakeholders.

ISO is currently working on developing certain biofuels standards, and the outcomes of this effort are eagerly awaited. The subsequent International Standards will help the broad development of biofuels worldwide.

When it comes to fuel quality, specifications for biodiesel require particularly close attention. This is due to the large variety of vegetable oils and animal fats that can be used for biodiesel production, and the variability in fuel characteristics that can occur with fuel produced from this feedstock. The European Union and the United States have developed their own unique biodiesel standards.

Classification

In a simplified way, biofuels can be sub-divided into two large categories: substitute for diesel (biodiesel) and substitute for petroleum (ethanol). This division is based on the key properties of the two products. On the one hand, biodiesel (which replaces diesel in cars) is produced from oil rich plants (e.g. rapeseed, sunflower, algae, etc.) by mixing the vegetable oil (90%) with methanol (10%) in the process called trans-estherification. On the other hand, bioethanol (which replaces petrol in cars) - also known as alcohol - is produced through the fermentation of sugar from cereals (wheat, maize, etc.) or sugary feedstocks (sugarcane, sugar beet).

Already from the above separation one can distinguish two different product markets: the diesel car fleet and the petrol cars segment.

Certification

Certification is the practical implementation of the standard or of the principles and criteria that should be achieved. This step requires a tracking method and a labeling process, and it implies a third party assessment of the management procedures with respect to a certain standard.

Guiding Principles

The difficulty of reconciling various information source types, technical standards and immaturity of markets made the work on this report challenging. To address these challenges the Task Force established a set of guiding principles.

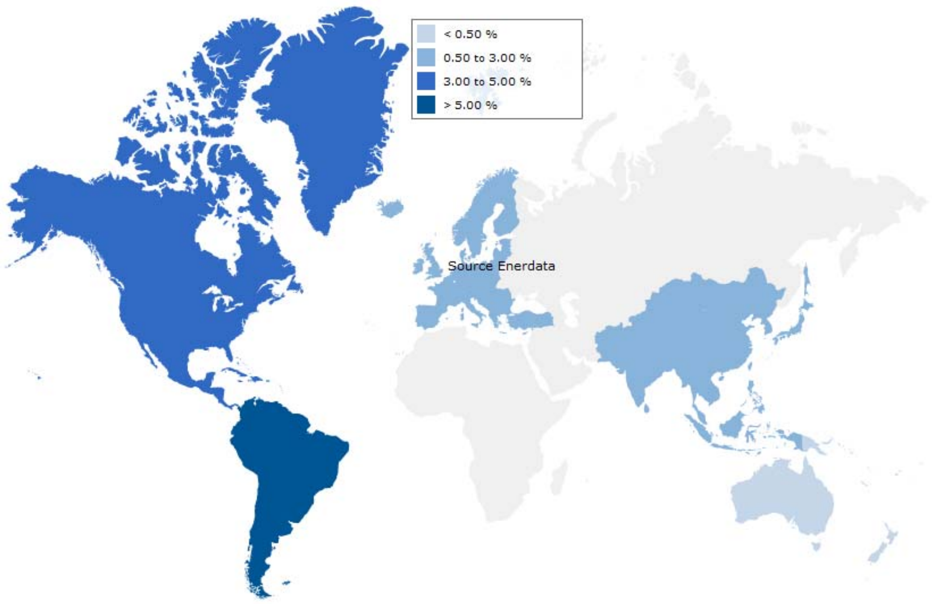
The guiding principles of this report aim at a common framework for public and private sector entities to consider and focus their efforts related to biofuels development and deployment. These principles are:

- Diversify supply of transport fuels, enhance security of supply, mitigate economic volatility related to oil price fluctuations, and improve global environment through sustainable biofuels practices.
- Identify technical criteria which can be used to standardise production of biofuels through different processes from different feedstocks.

- Pursue trade policies that support the growing use of regional transportation fuels.
- Foster the development of a sustainable biofuels industry through favourable tax, trade and public policy measures without impeding the development of a global marketplace for biofuels.
- Cultivate the competitive advantages of regional and national biofuels feedstocks (sugar cane, corn, cassava, sorghum, wheat, etc.), but not at the expense of destabilising fuel or food markets.
- Strengthen the investment flowing into biofuel development through transparency in public sector requirements and technological breakthroughs.
- Conduct a cradle-to-grave LCA for evaluation of economic, energy and environmental impacts using a common, objective and transparent methodology.
- Utilise existing literature to advance understanding of biofuels (see References and Bibliography).
- PROVISO: data quality is most robust for biofuels source types that have commercial scale production. Biofuels that are at demonstration scale have more technical information than those at pilot scale.

2. Biofuels in the Global Energy Scene

Share (%) of Biofuels in Road Transport 2008



Source: WEC/Enerdata

Global Outlook for Biofuels

According to the latest official statistics, global production of biofuels reached a record level of over 34 Mtoe in 2007 accounting for 1.5% of total road related fuel consumption. Preliminary figures for 2008 suggest the total production increase to nearly 39 Mtoe. There are a number of reasons for the strong interest in biofuels which is currently spreading around the world and driving increasing production of biofuels. These reasons include the need to diversify supply sources, mitigate the impacts of crude oil price volatility, reductions in biofuels production costs and growing concerns about the global environment. In some regions, development policies also play an important role.

This has encouraged many countries to advance their biofuels development plans and increase production targets. It is widely expected that globally production of biofuels will continue growing in the coming years, although at somewhat slower rates reflecting the downturn in global economic activities in 2008, concerns about biofuels economic and environmental sustainability, food prices and other aspects.

The International Energy Agency (IEA) estimates an average annual growth rate of 7%, which means that by 2030 biofuels would account for about 5% of the total road transport fuel demand, compared to approximately 2% today. USA which already today is the world's largest consumer of biofuels will increase its consumption even further. Europe will lead the global growth in demand in the coming years, and bioethanol will account for the dominating share of this growth.

In terms of land use, the projected growth would lead to an increase in the arable land used for biofuels production from about 1% of total available land today to approximately 2.5% in 2030.

Currently, two countries: Brazil and USA account for nearly 80% of global biofuels production. Both countries produce mainly bioethanol: USA from maize and Brazil from sugar cane.

Table 1: World Biofuels Consumption (Mtoe)

	2004	2010	2015	2030
OECD	**8.90**	**30.50**	**39.00**	**51.80**
North America	7.00	15.40	20.50	24.20
United States	*6.80*	*14.90*	*19.80*	*22.80*
Canada	*0.10*	*0.60*	*0.70*	*1.30*
Europe	2.00	14.80	18.00	26.60
Pacific	0.00	0.30	0.40	1.00
Transition Economies	**0.00**	**0.10**	**0.10**	**0.30**
Russia	*0.00*	*0.10*	*0.10*	*0.30*
Developing Countries	**6.50**	**10.90**	**15.30**	**40.40**
Developing Asia	0.00	1.90	3.70	16.10
China	*0.00*	*0.70*	*1.50*	*7.90*
India	*0.00*	*0.10*	*0.20*	*2.40*
Indonesia	*0.00*	*0.20*	*0.40*	*1.50*
Middle East	0.00	0.10	0.10	0.50
Africa	0.00	0.60	1.10	3.40
North Africa	0.00	0.00	0.10	0.60
Latin America	6.40	8.40	10.40	20.30
Brazil	*6.40*	*8.30*	*10.40*	*20.30*
World	**15.50**	**41.50**	**54.40**	**92.40**

Source: IEA World Energy Outlook, 2006 / updated 2009

Europe, on the other hand, produces mainly biodiesel and today accounts for nearly 90% of world biodiesel output. Today biodiesel is referred to as FAME. Biodiesel production in Europe is growing fast, mainly due to high subsidies and other incentives offered by governments. China and India are also major producers of biofuels, bioethanol in particular.

In the next few decades, global demand for transport fuel is expected to grow significantly – by up to 55% by 2030 compared to 2004. This will accelerate the growth in demand for biofuels, as they are expected to make an increasing contribution to meeting future energy needs of the mankind.

Demand for biofuels will grow all over the world, but particularly in developing countries, while USA and Europe are expected to remain the biggest consumers of biofuels. The majority of biofuels will continue to be produced and consumed domestically, although the international trade in biofuels is also expected to increase significantly. Bioethanol produced from sugar cane will account for the major share of exports, and Brazil is expected to remain the leading bioethanol exporter for the coming decades.

Besides the Americas and Europe, there are a number of other countries, mainly in Africa and Asia, which have the potential to become major producers and exporters of biofuels. South-East Asian countries which are large palm oil producers could develop competitive biodiesel production and export business. Their success, however, would to a large extent depend on the global trade policies and domestic subsidies, in particular in Europe and North America.

Some countries have set targets for domestic use of biofuels, either for use as pure fuel or blended with conventional fuel. In more than ten countries, oil companies are required to add a certain percentage of biofuels to the regular fuel they are selling. The official targets for the share of biofuels in the total road transport fuel consumption demonstrate significant variations across countries. The European Union, for example, aims at 10% biofuels of the total road transport demand by 2020. Brazil, on the other hand, targets to raise its production of bioethanol by 40% between 2005 and 2010.

To achieve these targets and objectives, governments offer a wide array of support measures and incentives, including special loan and grant programmes, tax credits, tax penalties on refineries which are not using biofuels, road tax exemption and others.

Despite the projected tripling of biofuels production from 20 Mtoe in 2005 to almost 60 Mtoe in 2015 and over 90 Mtoe in 2030, their share in the total road-transport fuel is not expected to surpass 4-5% by 2030. Biofuels production costs still remain comparatively high and substantial cost reductions are required for cost types to become commercially competitive.

A number of factors will influence the future of biofuels, in particular the use of available arable land for their cultivation, more efficient agricultural production methods, and development of more advanced biofuels technologies. Developments in the global oil market will continue to be the most influential factor driving the biofuels industry. A few clarifications of the terminology used in the report:

"First-generation biofuels" are biofuels made from sugar, starch, vegetable oil, or animal fats using conventional technology.

"Second-generation biofuels" are produced in processes which can use a variety of non-food crops. These include waste biomass, the stalks of wheat, corn, wood, and special-energy-or-biomass crops.

"Third generation biofuels" are crops which require further research and development (R&D) to become commercially feasible, such as perennial grasses, fast growing trees and algae.

Impact on food prices

The spreading concerns about the impact of increasing production of biofuels and possible competition with agricultural land and impact on the food prices require a holistic assessment since there is a number of various factors at play, including poor management of the agricultural sector during the last decades, unfavourable weather conditions, lack of investment in production capacity and infrastructure, distorted agricultural markets and the dismantling of support policies for domestic market in developed countries which all might have contributed to the recent increases in food prices all over the world. The United Nations Food and Agriculture Organisation estimated in 2008 that biofuels accounted for approximately 10% of the recent food price increases around the world. In certain countries biofuels have had a more significant impact on food prices, however it was mainly because of national agricultural support programmes and protectionist measures rather than increased production of biofuels.

Some projections indicate that the global demand for food is expected to double over the next 50 years and this would mean that food production will be primarily focused on available land and technology. The key success factors for the future of biofuels will be gradual expansion in cultivated land and considerable increases in agricultural productivity. This will require a broad political commitment, including introduction of badly needed land reforms, better irrigation, use of fertilizers and further development of transport infrastructure.

The development of second-generation biofuels based on conversion of cellulosic resources, such as grasses, sawdust and fast growing trees from non-food sources that can help to limit the direct competition between food and biofuel that is associated with mostly first-generation biofuels should be a priority for sustainability of biofuels.

> The use of appropriate biotechnological tools and techniques for improving the plants yield, drought tolerance and multiplication offers the best solution in case of unforeseen adverse environmental conditions.

Land Use

A major debate continues around the world about biofuels production and its impact on traditional agriculture, i.e. the perceived competition for land and the risk of displacing production of human and animal food by biofuels.

Although land devoted to fuel production could reduce land available for food production, this is at present not a serious problem. In the longer term, lignocellulosics are likely to become the primary source of biofuels. It is important in each particular case to evaluate the sustainability of raw material production to ensure that biofuels are developed in areas that do not affect the use of the basic resources of agricultural ecosystems such us soil, water, air and biodiversity. In addition, taking into account the climate and geographical diversity, initiatives for the use of semi-arid soils and other marginal lands could be implemented, for the benefit of supporting the development of rural populations in poor regions.

Analysis of areas today used for conventional crops production which are planned to be converted into biofuels producing areas is an important starting point for the evaluation.

Generally, in many countries, the land used today for agriculture and biofuels production accounts for a small share of the total arable land.

Large-scale production of biofuels could increase the price of agricultural commodities. This would benefit farmers, but might increase food prices. Farmers could also produce their own fuels. The expected continued growth in the use of biofuels would increase global demand for agricultural products and result in the creation of new jobs in harvesting, processing, distribution, etc. A biofuels industry that is local and where farmers produce fuel for their own use would produce direct and multiple benefits to a rural community. Soil productivity has also been increasing all the time, due to better chemical fertilisers, physical fertility and more efficient water economy.

No-Till Farming has reduced fossil fuel consumption, decreased carbon dioxide emissions (due to the absence of tillage) and promoted carbon sequestration (due to the increase in organic material). ***No-Till Farming*** production system is based on the absence of tillage, crop rotations and stubble coverage on the soil surface, and it has changed the old production patterns into a new type of agricultural process that reconciles the increases in productivity with good environmental practices.

Agricultural practices that are environmentally sustainable, socially accepted and that promote efficient use of energy should be supported. All possible energy crops in each region should be assessed, including the second generation biofuels crops - to promote the sustainable production (e.g. non-conventional oil seed and lignocelluloses materials).

Environmental impact assessment of biofuels production should be completed to evaluate all phases of the biofuels cycle, from the selection of the basic raw materials to the production techniques and technologies.

When examining biofuels production and consumption patterns in a variety of countries, it is important to take into account the fact that ecosystems, biodiversity, production methods and social environment, including impact on internal and cross-border migration, differ widely throughout the world. Thus, each particular area or country involved in biofuel production should be assessed individually.

Biofuels in selected countries

Due to its great biodiversity, climate and geography, the North, Central and South American region has become the most important biofuels producer and supplier in the world. In particular, USA, Brazil and Argentina are at present the leading actors in the market and have a much greater potential for the production and development of non-conventional biofuels than many other countries.

The following country case studies and Table 2 present summary information on biofuels for Argentina, Brazil, Canada, Colombia, Italy, Japan, Mexico, Nigeria and Sweden.

More detailed country information is included in Annex 1.

Argentina

There is no particular area allocated specifically for biofuels production. From the total soybean harvest a part is used as raw material for SME production. Mandatory blending of 5% (biodiesel and bioethanol) will be introduced on 1 January 2010. YPF started blending biodiesel in fossil fuels in June 2007. The biofuels market is highly regulated and features investment subsidies, tax relief, distribution quotas and other instruments. The main production technologies in use include Desmet Ballestra, Lurgi and a domestic range.

A Bioenergy Program 2007/2010 is being implemented with the participation of the Faculty of Agrarian Sciences, the Faculty of Applied Sciences to the Industry and the Faculty of Engineering of the National University of Cuyo, together with Argentina´s National Institute of Agricultural Technology (INTA) and YPF S.A. This program is now involved in the main INTA National Bioenergy Program, NBP which works through national projects and coordinates actions within INTA and with external actors at a national and international level. There has been significant increase in harvest and crushing capacity in recent years. No-Till Farming has been adopted as the leading practice for sowing. 80% of total soy agriculture is involved in this practice.

Brazil

Brazil has a total area of 851,000,000 hectares and is one of the biggest countries in the world. It has a population of 190,273,300 (2008 estimate), which means 45 hectares per capita. Brazil has a large-scale biofuels programme, which focuses on the two most important transportation fuels: gasoline and diesel. Bioethanol productivity has shown a huge increase since the late seventies when the bioethanol Program, PROALCOOL, was introduced. When it begun, bioethanol productivity was 4.6 litres/ha and today it is 7.6 litres/ha. Brazil can become a large bioethanol exporter. In 2007, bioethanol production was 22,500,000 m^3 while demand reached 19,000,000 m^3, and exports accounted for 3,500,000 m^3.

In 1993 a law was passed requiring 22% bioethanol addition to gasoline. Today, this requirement is more flexible and requires between 20 and 25% based on bioethanol availability. Biodiesel can be produced from a number of raw materials and the choice of the source is made depending on its availability and incentives that the Brazilian government. Biodiesel program is considered as a way to increase social and economic benefits for small, mainly family agriculture.

Fuel selection by consumers that have flexible fuelled vehicles is predominantly price-oriented, although there are some consumers who consistently chose gasoline or bioethanol. Flexible fuel vehicle fuel consumption is higher with bioethanol than with gasoline, and there is a break-even point which defines the price differential for filling up vehicle with gasoline or bioethanol.

Canada

However, statistics show that Canada imported about 100 million litres of total bioethanol (all grades – potable and denatured) in 2006, exclusively from the United States. Several Canadian companies import biodiesel from the United States as well.

Under the North American Free Trade Agreement (NAFTA), there is a free trade of renewable fuels among the United States, Mexico, and Canada. However, Canada has a tariff on bioethanol imported from Brazil (US$0.05 per litre).

In July 2007, the Canadian government announced that it would provide up to US$1.5 billion in incentives over nine years to producers of renewable alternatives to gasoline and diesel fuel.

The incentives are primarily for producers to "bridge the gap" between the current production level and the 3,000 million tonnes/year that will be needed to meet the 2012 targets, which were set by the government in December 2006 and passed into law in May 2008: Reaching an average of 5% renewable content in gasoline by 2010 and 2% renewable content in diesel fuel and heating oil by 2012.

Federal incentives provided through excise tax exemptions, amounting to US$0.10 per litre for bioethanol and US$0.04 per litre for biodiesel. A National Biomass Expansion Program providing US$140 million in contingent loan guarantees to encourage financing for new plants that produce bioethanol from biomass material such as crop residues.

Government Programmes include:

- The eco Agriculture Biofuels Capital Initiative (ecoABC) is a federal US$200 million, four-year capital grant program that provides funding for the construction or expansion of transportation biofuel production facilities. It appears funding is focused on cellulosic bioethanol.
- The ecoENERGY for Biofuels Initiative, which will invest up to US$1.5 billion over nine years from 2007 to boost Canada's production of biofuels.
- The ecoAUTO Rebate Program encourages Canadians to buy fuel-efficient vehicles, including FFVs. It offers rebates from US$1,000 to US$2,000 to people who, beginning March 20, 2007,

buy or enter a long-term lease (12 months or more) for a fuel-efficient vehicle.

Table 2: Summary of land use and biofuels production in selected countries

	LAND USE			PER CAPITA LAND USE		Total land area used for biofuel Hectares (ha)
	Total land area Hectares (ha)	Cultivated land area		Land Hectares (ha)	Cultivated land Hectares (ha)	
		Hectares (ha)	Share of total			
Argentina	276,689,000	31,900,000	11.5%	6.83	0.79	n/a
Brazil	851,000,000	66,600,000	7.8%	4.47	0.35	6,700,000
Canada	909,350,700	35,912,247	3.9%	27.58	1.09	n/a
Colombia	114,174,800	3,962,761	3.4%	2.60	0.09	100,000
Italy	30,100,000	12,900,000	42.8%	0.52	0.22	414,300
Japan	37,792,300	4,671,000	12.3%	2.95	0.36	0
Mexico	197,255,000	21,900,000	11.1%	1.77	0.19	n/a
Nigeria	92,000,000	34,000,000	36.9%	0.61	267.20	15,132,000
Sweden	41,100,000	2,647,700	6.4%	4.46	0.29	140,000

	Production costs (US$/litre)	Total demand (m3)	Total supply (m3)	Exports	Imports
Argentina	n/a	800.000 (Jan'10)	2.400.000	1.100.000	0
Brazil	ethanol: 0.29-.37 diesel: 0.65	19,000,000	22,500,000	3,500,000	0
Canada	n/a		ethanol: 715,500,00 biodiesel: 97,700,000	0	100 millio
Colombia	n/a	1,050,000	1,050,000	0	0
Italy	180/t	170.000	170.000	170.000	10.000
Japan	n/a	8,880,000	0	0	8,880,000
Mexico	1.10	n/a			50%
Nigeria	n/a	biodiesel: 300 bioethanol:38 0	60 80		
Sweden	n/a	ethanol: 359,000 FAME: 130,000	ethanol: 359,000 FAME: 130,0000	0	ethanol: 288,0 FAME: 100,0

Colombia's production of biofuels is based mainly on sugar beet/cane and for biodiesel follows the NTC5444 standard. Government is phasing in mandatory blend for biodiesel:

2008	(B5) in the Northern part of Colombia
2009	(B5) in the whole country
2010	(B10)
2012	(B20)

And for bioethanol:

2006	(E10) except north of the country
2010	(E10) provided the domestic production can meet demand in the country

(E14) is being studied

Italy

Biodiesel
Financial law requires a mandatory blending of 1% by 2007 (calorific value compared to automotive fuels), 2% by 2008, and 3% by 2009. The requirement for 2010 is still being defined. System of certificates is in place for monitoring of mandatory targets.
Penalty of 600 € per certificate (1 certificate = 10 gcal).

Bioethanol
Produced only for export to Northern Europe. ETBE is the second application to reach the mandatory target of the financial law introduced in 2007. It is difficult to estimate the volume of ETBE traded in Italy today, but from 2009, companies will be required to enter the biofuels blending data online directly on the Ministry's website.
Standards in use: BIODIESEL EN14214.

Japan

Japan does not have any domestic production of biofuels and has only recently begun to import them. In 2007 it imported 8,880,000 tonnes of ETBE.

In its National Energy Strategy developed by METI, Japan has set targets for automotive fuel which will help achieve its overall objectives, including reduction of its dependence on petroleum in the transport sector to about 80% by 2030.

The five main components of the strategy subset "Next Generation Automobile Fuel Initiative" are *Battery, Hydrogen, Clean Diesel, Biofuels and ITS.*

Introduction of bioethanol has been started and a country-wide development programme for production of bioethanol from lignocellulose will start in 2008.
Clean diesel promotion has also been started and development of new diesel fuels: GTL, FAME and BHD is about to commence.

Mexico

As many other developing countries, Mexico is approaching biofuels mainly from a social perspective. In 2007, Mexico took specific actions in order to incorporate biofuels into its energy mix, based on three principles: increase energy security, boost rural development and reduce negative environmental impacts, without jeopardizing food availability.

Mexico is a large automotive fuels consumer. In 2008, demand exceeded 780 thousand barrels a day of automotive gasoline as well as almost 300 thousand barrels a day of diesel. In real terms, Mexico consumes twice as much gasoline as the United Kingdom and 40% more diesel than Canada.

Despite being a large oil producer, Mexico's transport sector relies heavily on imports: more than 43% of automotive gasoline comes from abroad, whilst diesel imports reached 18% in 2008.

Petróleos Mexicanos (PEMEX) is the only state-owned petrol company, entitled to produce, distribute and sell automotive fuels across all the country. During the last few years, there have been a number of studies to determine the feasibility of the use of biofuels in Mexico.

In February 2008, Mexico approved the Law for the Promotion and Development of Biofuels. This law aims to create confidence and attract private investments, under a legal framework that defines the role of the State in guiding, coordinating and promoting the development of biofuels.

The main objective of this law is to promote the production of raw materials for the development of a biofuels industry, including agriculture, forest, waterweed and biotechnological processes. This should not risk Mexico's food security and sovereignty, as established by the Law for Sustainable Rural Development.

Finally, in order to promote and coordinate all the activities under this law, the Mexican Government has also created the Bioenergy Commission, including the Ministry of Energy, the Ministry of Agriculture, the Ministry of Environment and Natural Resources, the Ministry of the Economy and the Treasury.

Across the country, Mexico has more than 600 thousand hectares of sugarcane and approximately 60 sugar refineries, which produce nearly 5 million tonnes of sugar a year. Some of these refineries already have distilleries with output capacity of 167 thousand cubic meters (167 million litres) of bioethanol per year, including 33 thousand cubic meters (33 million litres) of anhydride bioethanol. However, a large percentage of this production is for the pharmaceutical and the liquor industry.

Furthermore, Mexico imports more than 50% of its bioethanol requirement. During the last couple of years, Petróleos Mexicanos has performed a series of studies in order to assure the technical feasibility of using bioethanol in its gasoline mix.

Results have shown that using bioethanol in small amounts does not significantly affect either the performance of vehicles, or the distribution systems.

An important issue related to the introduction of bioethanol in Mexico is the setting of a competitive price. Today, the price of bioethanol using sugarcane in Mexico rises to approximately US$1.6 per gallon, compared to US$1.3 or US$0.5 per gallon in the US or Brazil, respectively. In this sense, the price conditions in Mexico are still far from competitive compared to more technologically advanced countries.

Currently, Mexico produces small amounts of biodiesel, primarily for research purposes. In 2007, Mexico produced about 70 barrels of biodiesel per day, less than 0.02% of the domestic demand for regular diesel. Similar to bioethanol, the Mexican Ministry of Energy recommended the gradual introduction of biodiesel in the country.

Nigeria

The biomass energy resource base of Nigeria is estimated to be about 144 million tonnes per year. This includes wood, forage and shrubs, animal wastes and wastes arising from forestry, agricultural, municipal and industrial activities as well as aquatic biomass.

Nigeria's land area is about 79.4 million hectares of which 71.9 million hectares can be considered to be arable. This shows a huge potential for the production of biomass since an estimated 94% of Nigerian households are engaged in crop farming. Nigeria's aggregate annual crop production of 93.3 million tonnes of major crop yields far more quantity of straws, chaff, leaves and other biomass materials.

The extent of arable land holds promise for producing energy crops. These energy crops are not edible and as such cannot affect the food chain. Nigeria also produces an estimated 285.1 million tonnes of manure from her livestock population of 245.9 million, which can yield about 3 billion cubic meter of biogas annually. This is more than 1.25 million tonnes of fossil fuel oil per annum. Other possible biomass resources include aquatic plants such as water hyacinth and municipal wastes, both of which constitute major environmental problems.

3. Production and End-Use Technologies

General Aspects

Biofuels development has different drivers: the need to diversify energy mix, mandatory requirement for blending with conventional fuels, government support for the production, use and marketing of biofuels, legal frameworks and agricultural policies, just to name a few.

In order to identify the most critical issues for the sustainable production of biofuels around the world, certain criteria should be taken into account. This should include all phases of the biofuels cycle, from the selection of the basic raw materials to the production techniques and technologies, to end-use and emissions related to the entire process. It appears particularly crucial to establish an up-to-date, objective and transparent Biofuels Life Cycle Analysis framework at the international level. Ecosystems, biodiversity, production methods and social environment, including impacts on internal and cross-border migration, differ widely throughout the world. Different countries attach different priorities to these issues.

Geography and logistics

A general assessment of opportunities for biofuels production should include basic information such as location, associated transport and relevant infrastructure logistics. Some countries have their production base far from the main consumption centres and ports, in other countries it is the opposite. The origin of the crops or vegetable oils used for biofuels production is another aspect. Are they produced in the country or coming from other regions of the world?

For instance, in Argentina the raw material is produced in an area located 500 km from the biofuels processing plants but these plants, on the other hand, are located close to the ports and this is an unusual and beneficial situation. Biofuels production shall not rely on raw material coming from areas such as:

- Forests where there has not been significant human interference or where the last human intervention was long ago and where the natural species and processes have re-established themselves.
- Areas designated for nature protection purposes, unless evidence is provided that the production of biofuels does not interfere with those purposes.
- Forests and rainforests, unless they are managed using sustainable practices.
- Wetlands, i.e. land that is covered with or saturated by water permanently or for a significant part of the year, including peat land.
- Permanent grassland, i.e. rangelands and pasture land which have been under grassland vegetation and pasture use for at least 20 years and are not classified as forest.

Energy Crops

Energy crops are generally plants, trees or other herbaceous biomass which are grown and harvested specifically for energy production and use.

Biofuels Feedstocks

To ensure sustainable future for the biofuels industry it is important to identify all possible energy crops in each region, including the second generation crops (e.g., non-conventional oil seed and lignocelluloses materials) and algae. Intensive research, development and investment should be in place to increase the production of biofuels. There are three "generations" of biofuels:

- "First-generation biofuels" are biofuels made from sugar, starch, vegetable oil, or animal fats using conventional technology. The basic feedstocks for the production of first generation biofuels are often seeds or grains such as wheat, which yields starch that is fermented into bioethanol, or sunflower seeds, which are pressed to yield vegetable oil that can be used in biodiesel.
- "Second-generation biofuels" production processes can use a variety of non food crops. These include waste biomass, the stalks of wheat, corn, wood, and special-energy-or-biomass crops. Second generation (2G) biofuels use biomass to liquid technology including cellulosic biofuels from non food crops. Many second generation biofuels are under development such as biohydrogen, biomethanol, DMF, Bio-DME, Fischer-Tropsch diesel, biohydrogen diesel, mixed alcohols and wood diesel.
- "Third generation" feedstocks are crops which require further research and development (R&D) to become commercially feasible, such as perennial grasses, fast growing trees, and algae. They are designed exclusively for fuels production and are commonly referred to as "energy crops".

Catalysts and Neutralisers

Catalysts may be base, acid or enzyme material. Catalysts are required in biodiesel production to initiate the esterification reaction and promote an increase in the solubility to allow the reaction to proceed at a reasonable rate.

The most common catalysts used are strong mineral base such as sodium hydroxide (NaOH) and potassium hydroxide (KOH). After the reaction, the base catalyst must be neutralized with a strong mineral acid.

Biofuels for Transportation

In the past few years there have been important advances in the field of alternative transportation fuels, primarily bioethanol and biodiesel. Only biodiesel and bioethanol are considered in this report due to their similar inherent properties compared to fossil-based fuels, especially auto-ignitibility. There is a longer-term potential for other biofuels such as biobutanol and biogas but little research effort has been seen in either regular or small engines. (See ANNEX 2 for more detail)

Biogas

Biogas is used as transportation fuel in a number of countries although in Europe it is only Germany, Sweden and Switzerland that use biogas-fuelled vehicles to a somewhat significant extent.

For example, in Sweden, in 2008 approximately 15,000 cars and hundreds of buses and trucks were running on biogas. There are about 100 service stations in the country selling biogas. Biogas accounted for 0.3% of the total car fuel consumption, while Bio85 accounted for 0.4% and Bio95 for 2%.

In Germany, there are approximately 720 service stations, while Switzerland has 88 and Austria 48. By 2010, all petrol stations in Sweden will be required to offer customers either ethanol or biogas.

Biogas is produced from four main sources:

- Sewage treatment plants
- Landfills
- Cleaning of organic industrial waste streams
- Mesophilic and thermophilic digestion of organic waste.

Anaerobic digestion processes are often successfully applied to clean the liquid waste streams from food industries and other industries with large organic effluent. It s estimated that around 25% of biogas produced in Europe comes from industrial wastewater plants. Municipal organic waste is an important raw material for production of biogas but so far only 2% of the total production in Europe comes from municipal organic waste.

Biogas has to be upgraded to natural gas quality in order to be used in normal vehicles, designed for using natural gas. The most common technologies for biogas upgrading are the water scrubber technology and the PSA technology.

Gas upgrading is normally performed in two steps where the main step is the process that removes the CO_2 from the gas. Minor contaminants (e.g. sulphur compounds) are normally removed before the CO_2-removal and the water dew point can be adjusted before or after the upgrading (depending on process).

Biogas can be used in both heavy duty and light duty vehicles. Light duty vehicles can normally run both on natural gas and biogas without any modifications whereas heavy-duty vehicles without closed loop control may have to be modified if they are to run both on biogas and natural gas.

To promote the use of biogas, biogas vehicles enjoy special benefits in many Swedish cities, for example:

- Free parking
- Lower tax on biogas vehicles when used in commercial traffic
- No tax on biogas as vehicle fuel
- Exemption from road tolls for biogas vehicles.
- Special lanes for biogas taxis
- Financial support for investment in biogas vehicles

Bioethanol is an alcohol, made by fermenting any biomass with a high content of carbohydrates through a process similar to beer brewing. Today, bioethanol is made from starches and sugars. In the future, cellulose and hemicellulose fibrous material will be used.

Bioethanol is currently the most commonly used biofuel in an internal combustion engine and in fact, many countries have gasoline fuel standards that require 10% and 20% bioethanol blends. Depending on the controlled parameters in the manufacturing process, properties of fuel bioethanol can be varied and therefore, a standard is required.

Bioethanol is mostly used as a direct blending agent or/and as ETBE, with gasoline to increase octane and oxygenation and cut down carbon monoxide and other emissions. There are two broad groups of bioethanol feedstocks referred to as the "first" and the "second" generation feedstock. The majority of the first generation of feedstocks for bioethanol production are those that are also widely grown for food and animal feed, hence the current debate about biofuels impact on food." (See ANNEX 3 for more detail).

The first generation of biofuels feedstocks include:

i. Saccharine (Sugar Containing) Materials - These are currently being used for the production of sugar, or they have high component of simple sugar. These feedstocks are the easiest to convert to bioethanol and they are:

- Sugar Cane
- Sugar Beet
- Sweet Sorghum
- Fruits (eg. Grapes, apple, pineapples, pears, oranges, etc.)

ii. Starchy Materials -These feedstocks are rich in starch, a form of complex sugar. They can look as grains or tubers and include: Cereals such as Corn (Maize), Guinea Corn (Sorghum), Millet, Wheat, Rice, Barley, Cassava, Potatoes etc.

iii. Cellulose Materials – This is a much more complex sugar polymer found in plant materials crystalline in structure (lignin), and resistant to hydrolysis. Roughly, two-thirds of the dry mass of plant materials are a form of cellulose and hemicellulose. Lignin makes up the bulk of the remaining dry mass. The plant (cellulose) materials used as feedstock include:

- Plant wastes from industrial processes (e.g. paper and pulp).
- Forest wood wastes (e.g. chips and sawdust from lumber mills, dead trees, and tree branches).
- Energy crops grown specifically for fuel production, such as switchgrass, Miscanthus, Poplar, and
- Municipal Solid Waste (e.g. old newspapers).

Biodiesel is made by combining alcohol (usually bioethanol) with vegetable oil, animal fat, or recycled cooking grease. These materials contain triglycerides and other components depending on type. Some of the feedstocks are palm oil, coconut oil, canola oil, corn oil, cottonseed oil, flex oil, soy oil, peanut oil, sunflower oil, rapeseed oil and algae. Table 3 shows oil production averages of some crops.

Table 3: *Oil Production Averages of Some Crops*

Plant	Oil kg/ha
Oil palm	5,000
Coconut	2,260
Jatropha	1,590
Rapeseed	1,000
Peanut	890
Sunflower	655
Soybean	375
Hemp	305
Corn	145

It can be used as an additive to reduce vehicle emissions or in its pure form as a renewable alternative fuel for diesel engines. In the near future, agricultural residues such as corn stover (the stalks, leaves, and husks of the plant) and wheat straw will also be used.

Bioethanol

Flexible-fuel vehicles (FFVs) can operate on any blend of bioethanol with gasoline up to 100% (E100). About seven million FFVs are currently used in the USA running on fuel with 85% bioethanol (E85). US auto companies have committed to manufacturer a larger number of FFVs, in a wide variety of models, to be available at prices competitive with conventional vehicles.

All vehicles manufactured since 1978 can run on E10. Current warranties for conventional vehicles do not however cover damages if cars are run on levels of bioethanol higher than E10. In Brazil, given its high use of bioethanol, conventional gasoline vehicles are designed to run on high bioethanol content in gasoline (E25). Table 4 shows some of the feedstocks, their annual bioethanol yield and their greenhouse gas saving effect compared to petrol.

Biodiesel

Biodiesel can be legally blended with petroleum diesel in any percentage. The percentages are designated as B20 for a blend containing 20% biodiesel and 80% petroleum diesel, B100 for 100% biodiesel, and so forth.

Using B20 (20% biodiesel and 80% petroleum diesel) provides substantial benefits but avoids many of the cold-weather performance and material compatibility concerns associated with B100. B20 can be used in nearly all diesel equipment and is compatible with most storage and distribution equipment. B20 and lower-level blends generally do not require engine modifications.

Not all diesel engine manufacturers however cover biodiesel use in their warranties. Biodiesel contains about 8% less energy per gallon than petroleum diesel.

B100 - or other high-level biodiesel blends can be used in some engines built since 1994 with biodiesel-compatible material for parts such as hoses and gaskets. B100 use can increase nitrogen oxides emissions, although it greatly reduces other toxic emissions.

Bioethanol production

Bioethanol is produced by fermenting sugars mainly from cereals such as wheat, maize, triticale, rye, barley and from sugar cane or sugar beet. As for biodiesel, the production techniques of bioethanol evolved in time through sustained investment in research and development.

Advanced generations of bioethanol fuel offer the prospect of sourcing energy from an even wider range of feedstock. These feedstocks include non-food crops such as grasses; agricultural residues such as cereal straws and corn stover; industrial, municipal and commercial wastes and processing residues such as brewer's grain; and forest products and residues such as wood and logging residues.

Crop	Annual Yield (Litres/Hectare)	Greenhouse gas savings (% vs Petrol)	Comments
Miscanthus	7,300	37 - 73	Low input perennial grass. Bioethanol production depends on development of cellulosic technology.
Switchgrass	3,100 – 7,600	37 - 73	Low input perennial grass. Breeding efforts underway to increase yields. Higher biomass production possible with mixed species of perennial grasses.
Poplar	3,700 – 6,000	51 - 100	Fast growing tree. Completion of genomic sequencing project will aid breeding efforts to increase yields
Sugar Cane	5,300 – 6,500	87 - 96	Long season annual grass. Newer processing plants burn residues not used for bioethanol to generate electricity. Only grows in tropical and subtropical climates.
Sweet sorghum	2,500 – 7,000	No data	Low input annual grass. Grows in tropical and temperate climates, but highest bioethanol yield estimates assume multiple crops per year. Does not store well.
Corn	3,100 – 3,900	10 - 20	High input annual grass. Only kernels can be processed using available technology. Development of commercial cellulosic technology would allow stover to be used and increase bioethanol yield by 1,100 - 2,000 l/ha

Table 4: Selected Bioethanol Feedstocks and Their Annual Yields

Compared with conventional feedstocks, production of bioethanol from new feedstocks requires different technological (pre) treatment:

Bringing down the learning curves and decreasing production costs is a common goal for the research in new technologies in both biodiesel and bioethanol industries. However this can only be achieved if a favourable policy mix provides investors with a required return on investment.

Biodiesel production

Biodiesel is commonly produced worldwide as “Fatty Acid Methyl Ester” (FAME), derived from recycled or virgin vegetable or animal fats and oils. Although the transesterification process does not imply a complicated chemical reaction, it is particularly difficult to conduct it properly, and this calls for the highest industrial standards to ensure the quality of biodiesel. Today, biodiesel produced or marketed in Europe should meet the specifications of the CEN standard EN 14214.

Biodiesel is also produced from animal fats and used cooking oils (UCOs). Many European producers use recovered vegetable oil and animal fats from food processing, as they are readily available waste products and produce biodiesel with extremely beneficial greenhouse gas savings.

Several of the biggest biodiesel producers in Europe are agricultural businesses who add value to their oilseed products and processing capacities by converting oil to biodiesel.

Similarly, many are involved in the petrochemical industry as biodiesel production produces glycerine suitable for the cosmetics and pharmaceutical industries. Biodiesel production also results in increased availability of oilseed cake used for protein in animal feeds.

Algae biodiesel

While algae biodiesel has the same characteristics as conventional fuel, the production process can be also used to capture CO_2 from power stations and other industrial plants (synergy of coal and algae).

Algae oil production per acre is extremely high and does not even require agricultural land as it can be grown in the open sea, open ponds or on industrial land in photo bioreactors. Moreover algae biodiesel production can be combined with wastewater treatment and nutrient recycling, where polluted water (cleaned by algae) acts as a nutrient in their growth. But most importantly is that algae biodiesel jet fuel represents the best potential answer for the sustainability of the aviation industry today.

Issues related to Engines and Engine/Fuel Interface

Combustion characteristics of biofuels are different from those of regular fuels due to:

- differences in fuel flow,
- physical phase change,
- fuel atomization to chemical reaction, and
- heat exchange.

In addition to combustion issues, replacing fossil-based fuels with biofuels can lead to other concerns about engine performance, durability and fuel storage.

The effects of replacing fossil-based fuels with biofuels depends on the inherent properties of the fuels and engine operating principles.

Bioethanol Applications

Bioethanol is the most commonly used biofuel for spark ignition (gasoline) engine applications due to similar auto-ignitability properties to those of gasoline fuel. Currently, 5% of gasoline fuels sold in the US have been blended with ethanol. In addition, unlike biodiesel, oxidative stability is not a major problem for bioethanol. Since most small engines are spark ignition, the future of bioethanol in small engine applications appears to be very promising. (See Annex 4 for more detail)

Bioethanol can also be used as an additive in diesel engines to enhance combustion and reduce some emissions in spite of differences in auto-ignitability as compared to diesel fuels. It is useful to compare the properties of ethanol to regular gasoline and diesel fuels, Table 5.

Bioethanol generally has a higher auto-ignitability than gasoline, which is measured by octane number. It has a greater octane number (ON) than regular gasoline surrogates and incomparably higher ON than diesel fuels. In addition, bioethanol has lower viscosity, wider flammability limit and lower flash point than those of both gasoline and diesel.

Table 5: Fuel properties comparison.

(Highlighted portion indicates important parameters for auto-ignitability)

Property	Bioethanol	Gasoline	No. 2 Diesel
Chemical Formula	C_2H_5OH	C_4 to C_{12}	C_3 to C_{25}
Molecular Weight	46.07	100–105	≈200
Carbon	52.2	85–88	84–87
Hydrogen	13.1	12–15	33–16
Oxygen	34.7	0	0
Specific gravity, 60° F/60° F	0.796	0.72–0.78	0.81–0.89
Density, lb/gal @ 60° F	6.61	6.0–6.5	6.7–7.4
Boiling temperature, °F	172	80–437	370–650
Research octane no.	108	90–100	--
Motor octane no.	92	81–90	--
(R + M)/2	100	86–94	N/A
Cetane no.(1)	--	5–20	40–55
Fuel in water, volume %	100	Negligible	Negligible
Water in fuel, volume %	100	Negligible	Negligible
Freezing point, °F	-173.2	-40	-40–30b
Centipoise @ 60° F	1.19	0.37–0.44a	2.6–4.1
Flash point, closed cup, °F	55	-45	165
Reid vapour pressure, psi	2.3-2.5	8-15	0.2
Blending Reid vapour pressure, psi	18-22	8-15	--
Heat of Vaporization, Btu/lb @ 60° F	362-400	140-170	≈100
Higher Heating Value, Btu/lb (liquid fuel-liquid water)	12,800	18,800–20,400	19,200–20000
Lower Heating Value, Btu/lb (liquid fuel-water favor)	11,500	18,000–19,000	18,000–19,000
Auto-ignition temperature, °F	793	495	≈600
Flammability limits, vol%	3.3-19.0	1.0-8.0	-
Btu/lb air for stoichiometric mixture @ 60° F	44	≈10	≈8
Mixture in vapour state, Btu/cubic foot @ 68° F	92.9	95.2	96.9c
Fuel in liquid state, Btu/lb or air	1,280	1,290	–
Specific heat, Btu/lb °F	0.57	0.48	0.43
Stoichiometric air/fuel, weight	9	14.7a	14.7
Volume % fuel in vaporized stoichiometric mixture	6.5	2	–

Table 6: Summary of benefits and drawbacks in using bioethanol as a gasoline substitute

Categories	Benefits		Drawbacks	
	Advantages	Reason	Disadvantages	Reason
Engine performance	Better combustion efficiency	Operability in high compression ratio engine due to its high octane Increases in volumetric efficiency from cold manifold Faster laminar flame speed of oxygenated fuels Possibly lean combustion	Less power output Possibly poor combustion characteristics	Less heating value (per mass) Phase separation
Emissions	Lower HC and CO (without consideration of evaporative emissions) Lower emissions related to aromatic compounds Lower VOC emissions (for ethanol blends) Lower sulfur contents	More complete combustion/ lean – combustion Less aromatic octane enhancers Less volatile organic compounds Derived from organic feedstocks	Higher particular HC emissions, such as acetaldehyde (ethanol), formaldehyde, methane, ethylene and acetone Higher carcinogenic evaporative emissions (for the blends with small-to-medium ethanol fractions)	Unique ethanol oxidation path High evaporative pressure/ Distillation temperature
Engine durability	E20 can reduce injector tip for a gasoline direct injection engine.	Synergistic effects of high latent heat and aromatic and sulfur content reductions	Vapour lock (only for the blends with small-to-medium ethanol fractions) Phase separation Material compatibility (both metal and elastromer)	High volatility Presence of water Oxy polarity/ Water contamination/ Ionic contamination such as chloride ions or acetic acid
Storage and Handling			Leakage from storage corrosion	Water content and electricity conductivity

Bioethanol as a Gasoline Substitute

Bioethanol in gasoline engine applications is today the most practical and widely used biofuel and is potentially the most feasible renewable replacement for small gasoline engine applications (Table 6).

Bioethanol in Diesel Engines

Despite the fact that the cetane (reverse of octane) numbers of ethanol and diesel fuels are at the different extreme ends, adding ethanol to diesel fuel has been done in order to enhance combustion efficiency and reduce some emissions. The ethanol-diesel blend is referred to as e-diesel.

Issues with Bioethanol – All Applications

There have already been some solutions to address the challenge of using ethanol/ethanol blends in both SI and CI engines. Common disadvantages of applying ethanol to both SI and CI engines are lower output, greater HC emissions (specific types), phase separation and material compatibility.

The lower energy content (of both FAME biodiesels and ethanol) cannot be altered; however, the amount of injected fuels in each cycle can be increased by redesigning and presetting an engine so that load specification is satisfied.

HC emissions (especially acetaldehyde, formaldehyde, methane, ethylene and acetone) that occur due to the oxidation of ethanol-related fuel can probably be reduced by lean combustion, which can be generated with either air enrichment or EGR dilution.

Phase separation is perhaps the most salient drawback to ethanol use, causing blend degradability and therefore poor combustion quality. The primary solution is to have a dry distribution system or add either emulsifier or co-solvent additives. Gasoline composition, hydrocarbon families, also have an important role in ethanol/gasoline mixture stabilization.

Real-time blending of separated ethanol and gasoline is another possibility to solve phase separation problems. This can be done by using a modified carburetor. Material compatibility problems are caused by oxy-polarity of ethanol, which enhances dissolvability, electric conductivity and water affinity of the blends.

Bioethanol is incompatible with elastomeric and some metallic materials (such as aluminum, zinc, tin, lead-based solder or brass). Since material compatibility is caused by the polar nature of bioethanol, the best solution to this problem is to avoid incompatible materials although selected lubricants might partially reduce the severity of the problem.

In SI engines, bioethanol-gasoline blends have higher volatility, increasing vapour lock potential and evaporative emissions especially in the hot summer. One effective solution is to control the utilization period of ethanol blends or to change gasoline light front composition to mitigate volatility increase caused by bioethanol addition. Another approach to reduce evaporative emissions is to avoid using plastic material for a fuel system as permeability of ethanol through plastic material is high.

Finally, a canister can be used to purify the vented air through fuel. However, backfire of a canister is possible and troublesome, and occur especially with old canisters that have HC buildup.

Cold weather startability is another major problem of using enriched-to-pure ethanol blends in an SI engine, caused by inherently high latent heat of evaporation and low Reid Vapour Pressure (RVP).

Adding VOC is one solution; however, it increases VOC related emissions. Another solution is to install a reliable heating device to a fuel system. The drawbacks to this solution are cost and start-up retardation. In CI engines, pre-combustion and multi-injection can be used to mitigate the risk of having severe combustion caused by too long ignition delay time.

Phase separation can be prevented by removing water from the fuel. Also, adding some emulsifiers, additives and aromatics also prevents phase separation of diesel-bioethanol blends.

Table 7: Summary of benefits and drawbacks in using biodiesel as a diesel substitute

Categories	Benefits		Drawbacks	
	Advantages	Reason	Disadvantages	Reason
Engine performance	Better combustion efficiency	Additional oxygen in fuel	Less power output Poor atomization	Lower power density (per mass) Relatively higher viscosity and heavier molecular weight
Emissions	Reducing THC, CO Less sulfur content, compared to diesel Increase NO_x after-treatment efficiency Biodegradability	Better combustion due to additional oxygen Inherent properties Less sulfur Derived from organic substances	Increased NO_x	Hotter combustion due to additional oxygen
Engine durability	Can be used in a new diesel without major modification Reduced wear of metallic components	Same auto-ignitibility range as diesel Enhanced lubricity	Broken seals Poor operability in cold weather Fuel system encumbrance Engine oil degradability Injection tip	Oxy-polarity in esters makes biodiesel a good solvent High pour point and cloud point temperatures Dissolved residuals from a fuel tank that used to be filled with 100% diesel Escaping fuel from a combustion chamber Decompose during ignition delay time and high cloud point temperature
Storage and Handling	More difficult to catch file	High flash point	Fuel degradability	Sensitive to water, temperature, microbial creatures and oxygen

Biodiesel Applications

The adoption of biodiesel/diesel blends is very promising since properly designed blends have proven to have better combustion efficiency and lower emissions than diesel fuel alone. However, some properties of biodiesel and engine durability problems limit the maximum fraction of biodiesel. Biodiesel has good lubricity and can be used to improve lubricity of diesel fuel.

Biodiesel as a Diesel Substitute

Biodiesel can be used as a direct substitute for diesel, or in a blend with diesel. Table 7 presents the advantages and drawbacks of using biodiesel as a diesel substitute. Several technical improvements on both fuels and engines are still required, which might lead to slightly higher costs of operating a diesel engine with biodiesels.

Advantages

The outstanding advantage of using biodiesel blends as engine fuel is their adaptability to a diesel engine without any major engine modification, especially when a limited fraction of biodiesel is introduced to the blend.

The maximum amount of biodiesel blended with regular diesel depends on engine models. Newer engine models from large engine manufacturers can tolerate (and warranty) as high as 20% biodiesel in the blend. However, use of B20 or higher fractions of biodiesel requires some precautions on fuel degradability, fuel filters, cold weather operation, and maintenance.

Additional oxygen in Fatty Acid Methyl Ester (FAME) biodiesels improves fuel oxidation (combustion), leading to more spontaneous combustion and better combustion efficiency. At the same time, it reduces the total energy content of the fuel by ~10% (on a mass basis) primarily because oxygen carries less energy than heavy hydrocarbon molecules.

This is the primary reason for reduction of engine power output when using 100% (neat) biodiesel. However, at lower biodiesel fractions, there is some discrepancy in the literature about the effect on power output – some studies show higher power output whilst others report a reduction.

This is likely due to the combined effects of better efficiency and lower heating value. Furthermore, engine power output can be affected by other parameters (e.g. intake manifold conditions, fuel temperature, injection timing, and flow inside a cylinder).

More complete combustion of biodiesel can substantially reduce unburned hydrocarbon (HC) and carbon monoxide (CO) emissions. However, biodiesel can increase NOx emissions as the combustion temperature is higher. NOx emissions can be reduced by replacing some of the FAME biodiesel with kerosene or Fischer-Tropsch diesel. In addition, for an engine with a catalytic converter, inherently low sulphur in biodiesel leads to a better NOx catalytic conversion efficiency and therefore, after-treatment from a biodiesel engine probably emits less NOx.

Fuel lubricity helps prevent engine wear and extends engine life. In regular diesel fuels, the natural sulphur content enhances lubricity. However, tighter sulphur regulations have caused lubricity problems. Fortuitously, biodiesels derived from vegetables oils have an ultra low sulphur level yet also have high lubricity. Better lubricity is attributable to oxy-polarity if esters and high molecular weight of fatty acid chains.

The high lubricity of biodiesel extends the lifetime of fuel injection systems as well as metallic components that have sliding contacts with each other. Finally, it is safer to handle and store biodiesel at high temperature as biodiesel has a high flash point due to its composition of non-volatile fatty acid methyl esters (FAME).

In recent years, for environmental reasons, a number of countries have been reducing significantly the amount of sulphur contained in automotive fuels. In the specific case of diesel, it is now common to find diesel with 15 parts per million of sulphur rather than 300, 500 or even 1,000 parts per million which used to be the norm in the 1990's.

However, a negative side effect of reducing sulphur in regular diesel is a significant decrease in lubricity. Therefore it is necessary to add chemical components to maintain the required standards. It has been proved that the use of biodiesel, in relatively small amounts (0.5 – 2.0 % in volume), can help significantly increase lubricity, even to similar levels once obtained using regular chemical additives.

Issues with Biodiesel

Engine durability is the real challenge of using biodiesel blends as an engine fuel. Oxy-polarity of esters makes biodiesel a good solvent, causing two major problems. Firstly, elastomeric seal degradability can increase, including swelling, shrinkage, embrittlement and changes in physical properties such as hardness and tensile strength.

Secondly, high solubility of biodiesel could cause fuel system encumbrance especially when used in an engine normally operated with regular diesel fuels. During the use of the regular diesel fuels, deposits accumulate in the fuel tank. Addition of biodiesel loosens these deposits and re-introduces them into the fuel stream.

High cloud point and pour point temperatures of biodiesel reduce thermal stability and limit the cold weather operability of both pure biodiesels and blends. Problems at the injector tip might occur when using biodiesel, which with soybean biodiesels can break down at 430°C to 480°C.

This indicates the potential to decompose during ignition delay time which could cause deposits at the injector tip, thereby shortening the life time and could cause injector failures.

It is difficult to store biodiesel over a long period of time due to fuel degradability which can be divided into four main categories: hydrolysis, thermal degradability, biological degradability and chemical degradability. Since biodiesel is very sensitive to water, temperature, microbial action and oxygen, unpleasant changes of biodiesel properties can occur rapidly (within a few months).

Potential Solutions

Engine power reduction when using biodiesel can be avoided by using a blend instead of neat biodiesel. In addition, some engine configurations (such as intake conditions and injection timing) can be adjusted to obtain the power output such that it satisfies the power requirements for particular applications.

Poor atomisation can be solved by redesigning an injector and reducing fuel viscosity. Engine durability problems due to the use of biodiesel require some modifications on both engines and fuels.

Although some additives can improve cold temperature properties of biodiesel, further improvement is still necessary for reliable operation in cold weather areas.

Despite greater amounts of NOx emissions produced from biodiesel combustion, they are not deemed problematic for an engine with a catalytic converter. In fact, NOx emissions produced by a biodiesel engine with a catalytic converter might be lower than a regular diesel engine due to the lower sulphur content of biodiesel.

Preventing an external flame from entering a fuel tank is important due to the extended flammability limit and lower flash point. The risk can be mitigated by a flame arrestor. It is necessary to evaluate the effects of biofuels on the transport sector. Engines should be designed for or adapted to using biofuels.

Technology Outlook for Biofuels

The recent developments in biofuels suggest that the rapid growth of biofuels use could continue for decades.

The potential for biofuels is particularly large in tropical countries, where high crop yields and lower costs for land and labour provide an economic advantage. It has been estimated that worldwide sugar cane production could be expanded so that crop alone could displace about 10 percent of gasoline use worldwide.

Table 8: Feedstock Logistics and Technology R&D Needs

<table>
<tr><th colspan="2">Feedstock System Logistics Design and Management</th></tr>
<tr><td colspan="2">

- **Design of Feedstock collection, Storage, and Pre-processing system will be based on:**
  - **Enhanced systematic economic analysis of cost reduction options**
  - **Feedstock type**
  - **Support a wider variety and larger quantity of feedstocks**
  - **Regional geography**
  - **System ownership structure**
- **Challenges:**
  - **Improving soil productivity**
  - **No water environments**
  - **Reduced labour cost**
  - **Reduced fuel costs**

</td></tr>
<tr><th colspan="2">Research and Technology Development Needs</th></tr>
<tr><th>Near Term (2008-2012)</th><th>Long Term (2012-2025+)</th></tr>
<tr><td>

- **New technologies required to support efficient, economic and sustainable biomass collection and handling. Includes:**
  - **Harvesting equipment designed specifically for biomass to bioenergy applications**
  - **Nutrient recycling**
  - **Feedstock movement processes**
  - **Advanced harvesters for residue collection**
  - **In-forest grinders**
  - **Technologies for effective separation of oils, proteins and carbohydrates**
  - **Fractionation technology**
  - **Improved feedstock analysis**
- **Regional specific feedstock yield research to identify which species/crops provide best biofuel/energy for a specific local condition**
- **GIS and remote sensing for land use planning**
- **Gray water and water treatment**
- **Algae feedstocks**

</td><td>

- **R&D on biofuel feedstocks with low water demand**
- **Improving the utility of crop residues**
- **Hydrogen production**

</td></tr>
</table>

The expansion in biofuels production and use will require the development of new equipment and methods to collect, store and pre-process biomass in a manner acceptable to biorefineries. These include:

- Harvesters and collectors that remove feedstocks from crop land and out of forests.
- Storage facilities that support a steady supply of biomass to the biorefinery, in a manner that prevents material spoilage.
- Pre-processing/grinding equipment that transforms feedstocks to the proper moisture content, bulk density, viscosity, and quality.
- Transportation of feedstocks from the field to the biorefinery.

Table 9: Research and Technology Development Needs	
Near Term (2008-2012)	**Long Term (2012-2025+)**
• **General:** o **Process integration** o **Pollution control equipment** • **Biochemical conversion** o **More cost effective processes** o **Increase the variety of products available** o **Increase scale of systems** o **Minimise water use and waste water generated** o **Improved use of C-5 and C-6 sugars** • **Thermochemical conversion** o **More cost effective processes** o **Reduction in environmental impacts of production** o **Gasification** ▪ **Enhanced feed systems** ▪ **Lower tar production** ▪ **Economics at smaller scale** ▪ **Gas cleaning** ▪ **Better synthesis catalysts** o **Pyroloysis liquids** ▪ **Improve qualities of biofuels** ▪ **Separation by or after pyrolysis** ▪ **Oil upgrading and extraction** ▪ **Catalysts** o **More thermo-tolerant biological catalysts** o **Highly selective catalysts to improve efficiency**	• **General** o **Integrated carbon capture and storage** o **Use co-products as chemical feedstocks** o **Conversion processes to transform proteins and lignin's into co-products** o **Ionic liquids supercritical fluid membrane** o **Consolidated bioprocess one-stop shop** • **Catalysts:** o **Development of highly selective thermochemical catalysts** o **Development of improved mixed alcohol catalysts**

While many of the high priority technical barriers will need to focus on reducing the currently high costs of harvesting, pre-treatment and separations, the hurdles that must be overcome fall into the following two main areas: Logistics and Technology R&D needs.

Processing/Conversion Science and Technology

- Processing and conversion includes a range of activities from separations in the pre-processing/processing stage to conversion of biomass feedstocks into useful fuels.
- The production of biofuels from feedstocks can be achieved through two very different processing routes. They are:

✓ Thermo-chemical – where pyrolysis/gasification technologies produce a synthesis gas from which a wide range of long carbon chain biofuels can be reformed.

✓ Biochemical conversion – in which enzymes and other miocro-organisms are used to convert cellulose and hemi cellulose components of the feedstocks to sugars prior to their fermentation to produce ethanol

A high priority for activities is in the development if modular pre-treatment, processing and fractionalization methods. These "on-farm" methods can reduce feedstock transportation and overall life-cycle costs.

- For actual biofuel production, the challenge is to reduce the cost.
- However, to reduce the cost, there needs to be wider product usage and consumption.

Productivity Improvement in Agriculture through Biotechnology

Agriculture is expected to feed an increasing global population, which may reach 8 billion people by 2020, of whom 6.700 billion will be living in developing countries. Although the rate of population growth is steadily decreasing, the increase in absolute numbers of people to be fed may still put a significant strain on the world agriculture. (See ANNEX 5 for more detail)

The technological challenge is to achieve this agricultural productivity improvement without destroying the global natural resource base. New technologies, such as biotechnology, if properly focused, offer a responsible way to enhance agricultural crop productivity for now and the future.

The main biotechnological applications in crop biotechnology include tissue culture, marker-assisted selection and transgenic technology. Tissue culture includes micropropagation; embryo rescue; plant regeneration from callus and cell suspension; and protoplast, anther and microspore culture, which are used particularly for large-scale plant multiplication.

Micropropagation has proved especially useful in producing high quality, disease-free planting material of a wide range of crops. Tissue culture also provides the means to overcome reproductive-isolating barriers between distantly related wild relatives to crops through embryo rescue and *in vitro* fertilisation or plant protoplast fusion.

Molecular marker technology is useful for assisting and accelerating selection by conventional breeding. It is a powerful way to identify the genetic basis of traits and is used to construct linkage maps to locate particular genes that determine beneficial traits. Using molecular markers, genetic maps of great detail and accuracy have been developed for many crop species.

Markers are particularly useful for analysing the influence of complex traits like plant productivity and stress tolerance and are being employed to develop suitable cultivars of the major crops.

Generation of genetically modified transgenic plants with a range of added traits uses advanced recombinant DNA techniques including genetic engineering and cloning. Several transgenic cultivars of major food crops, such as soybeans, maize, canola, potatoes and papayas, have been commercially released incorporating genes for resistance to herbicides, insects and viruses.

It is estimated that the global area planted with transgenic crops has risen from 1.7 million hectares in 1996 to 44.2 million hectares in 2000.

Crop improvement continues to benefit from advances in plant molecular biology and genomics. The completion of the genome sequence of the mustard (*Arabidopsis thaliana)* and rice and the continuing work on functional genomics has tremendous direct benefits both for dicotyledons and monocotyledons.

The increase in understanding of gene regulation and expression will allow crops to be modified to provide food, fibre, medicine and fuel as well as tolerance to environmental stresses. The tools are in place to meet future food demand through increases in crop productivity with less land and water to meet the demand of the population increase.

It is however, important to recognise that transgenic gene escape and genetic erosion and new products of biotechnology can cause possible environmental risks. Mainly involving genetically modified crops; such concerns have been raised. Adequate bio-safety regulations, risk assessment of transgenic crops and establishment and compliance with appropriate mechanisms and instruments for monitoring use are needed to ensure that there will be no harmful effects on the environment or for the users.

With the growing global population, the demand for food and cash crops will continue to increase. However, this growth curve may not herald an increase in resources, e.g. available farmland, as has been the case in past years. A synergy of resources and farm practices would be required to achieve significant improvement in yield based on new plant varieties and farming technologies.

Productivity must increase on all farmland, not just in highly productive areas. More variety and assortment of crops other than the three key cereals need to be developed. The potential for resource conservation such as an Integrated Nutrient Management Supply system needs to be fully realised.

Livestock production looks to raise the quantity of livestock in circulation such as beef cattle, sheep, and hogs and establish dairy farms, poultry/egg farms, and animal specialty farms, such as apiaries (bee farms) and aquaculture (fish farms). Crop production includes the growing of cash grains, such as wheat, corn, and barley; field crops, such as cotton and tobacco; vegetables and melons; fruits and nuts; and horticultural specialties, such as flowers and ornamental plants.

With the growing demand to increase food production, the pressure falls on farmers to improve on farm practices. The first objective would be to tackle declining soil quality, caused by soil tillage. As a result, No Till/Conservation Agriculture (NT/CA) has been developed.

This is an effective technique in reducing soil degradation. Using this method, crop residues or other organic amenities are retained on the soil surface and sowing/fertilising is done with minimal soil disturbance.

Although some obstacles may present themselves during a transition to this practice, previous experience seems to indicate that many problems are temporary and become less important as the no-till system matures and equilibrates. Judicious use of crop rotation, cover crops and same soil disturbance may help reduce agronomic risks. Farmers switching to continuous no-till must often seek new knowledge and develop new skills and techniques in order to achieve success with this different way of farming.

Integrated Pest Management

The awareness of the effect of globalisation on the environment, pressure from activist groups and concerned citizens, governments and producers must increase food production without damaging the ecological foundations of agriculture. This underlies the need for the generation and diffusion of new technologies to produce sufficient food to protect the environment and human health. An integrated pest management (IPM) system incorporates such technology.

Insect pests, diseases and weeds are the major constraints limiting agricultural productivity.

Almost a fifth of overall crop production is lost to insects. Emerging problems such as insecticide resistance, secondary pest outbreak and resurgence further add to the cost of plant protection.

In developed countries, losses in production are on the rise. New cropping patterns and intensive agricultural practices have led to the emergence of new pests. To combat this, IPM systems apply a combination of pest control strategies, particular to the region involved. These include the use of biological, chemical, cultural and resistant variety controls. IPM is thus more complex to implement, as it requires skill and understanding of pest monitoring and dynamics, and *en masse* co-operation by producers for this to be effective.

IPM is an ecologically based strategy focussing on long-term solution of pest-control by a combination of techniques such as biological control, habitat manipulation, modification of agronomic practices, and use of resistant crop varieties. Using a single tactic to control a specific organism does not constitute IPM, even if is an essential element of the IPM system. Integration of multiple pest suppression techniques is probably the best way of sustaining long-term crop protection.

Pesticides may be used to remove/prevent the target organism, but only when assessment by means of monitoring and scouting indicates they are needed to prevent economic damage. Pest control tactics, including pesticides, should be carefully selected and applied to minimise risks to human health, beneficial and non-target organisms, and the environment.

The foundation for this system is the creation of a database of susceptible pest types and their effects. Information obtained from this database aids selection of the best possible combinations of the pest-control methods.

IPM also looks at the continuous pest resistance breeding process, using genetic techniques to combat pathogens with the ability to co-evolve with their host. This is a peculiarity among plant pathogens. An example of this is the incorporation of genetic material from *Bacillus thuringiensis* (Bt), a naturally occurring bacterium, in cotton, makes the plant tissues toxic to the insect pests.

An IPM should also include crop production practices that make the environment less susceptible to pests. Crop rotation, fallowing, manipulation of planting and harvesting dates, row spacing and destruction of old crop debris are some examples of cultural methods used to manage pests. Planting of cover crops, nectar-producing plants and inter-planting of different crops to provide habitat diversity to beneficial insects are important management techniques.

Examples of an IPM system practised include the placement of plastic-lined trenches in potato fields to trap migrating Colorado beetles, installation of dead as well as live bird perches in cotton and chickpea fields has proved effective in checking the bollworm infestation. These constitute some physical control measures. Biological control measures of IPMs include augmentation and conservation of natural enemies of pests such as insect predators, parasitoids, parasitic nematodes, fungi and bacteria.

Direct chemical control measures would involve the spraying of pesticides, which are used to keep the pest populations below economically damaging levels when they cannot be controlled by other means. Pesticides include both synthetic and plant-derived pesticides. Ideally, pesticides should be used as a last resort in IPM programmes because of the potential negative effect on the environment.

Botanical pesticides are a potential replacement for their synthetic counter-parts and can be prepared in various ways, e.g. as simple as raw crushed plant leaves, extracts of plant parts, and chemicals purified from the plants; pyrethrum, neem, tobacco, garlic, and pongamia formulations are some examples. Some botanicals are broad-spectrum pesticides and are generally less harmful to the environment, because of their quick degrading property. They are less hazardous to transport but the major advantage is that these can be formulated on-site by the farmers themselves.

Integrated Plant Nutrient Management & Supply (INMS)

Continuous crop production without adequate management tends to reduce nutrient reserves in the soil. If left unchecked, this cumulative depletion leads to a reduction in agricultural production and crop yield, soil fertility and degradation. Techniques to conserve and add nutrients to the soil by the application of organic or inorganic fertilisers can help to maintain and increase soil nutrient reserves.

However, one must note that an over supply of nutrients can cause serious problems including harm to end-product consumers, damage to the plants themselves, etc. The relative low cost of fertiliser is also a problem in that it leads some farmers to apply them in amounts far exceeding plant needs, as well as in quantities far exceeding the soil capacity to hold nutrients.

An Integrated Plant Nutrient Management and Supply (INMS) system has been developed in many countries and research institutes to strike this balance.

The application of regulated measures for both organic and non-organic fertilisers is one approach by an INMS system to correct nutritional imbalance. This not only increases crop yield, but also reduces the need to cultivate unsustainable marginal lands. In Kenya, the application of nitrogenous fertiliser on nitrogen-poor soils increased maize yields from 4.5 to 6.3 metric tonnes per hectare, while application of a less-appropriate fertiliser increased yields to only 4.7 tons per hectare.

Incorporating the use of (manmade) non-organic fertilisers is a crucial resource-tool of INMS. Governments involved in support of INMS programs can boost production potential by enacting policies/programs making organic and inorganic fertilisers easily available and affordable.

An INMS system also looks at utilising waste as an extra plant nutrient source. Although this is a relatively poor substitute for commercial fertilisers, wastes, in the form of urban sludge, improve soil structure and both contain secondary and micronutrients as well as NPK.

In addition to the above, the use of waste (especially treated waste) as a supplement to fertilisers is economically viable as it reduces the cost of disposal and health risks associated with landfill disposal. This is extremely beneficial to farmers who cannot afford inorganic fertilisers.

An INMS system also looks at reducing the occurrence of volatilisation, a process by which crops lose nitrogen into the atmosphere. This aids improving the efficiency of nutrient uptake by crops. New techniques, such as deep placement of fertilisers and the use of inhibitors or urea coatings, have been developed to address this problem.

An Integrated Nutrient Management Supply system requires a range of factors in the areas of research, extension, evaluation and dissemination of technologies.

Different climate, soil types, crops, farming practices and technologies mandate that a correct balance of nutrients necessary for any one farm may be quite different from that for a farm in a different location. In Africa for example, the challenge is intimidating because of severe climatic and soil conditions and the diversity of smallholder farmers.

Successful INMS adoption programs thus must facilitate an exchange of information between farmers, extension programs, and researchers that help these participants learn about what actually works for farms in their area. Adoption programs also require greater monitoring and testing of plants and soils to ensure that INMS establishes the best environment for plant growth.

A paradigm shift to organic agriculture

Organic agriculture, according to USDA definition, is a system that is managed in accordance with the Organic Foods Production Act and regulations to respond to site specific conditions by integrating cultural, biological and mechanical practises that foster cycling of resources as well as promoting ecological balance and conserving biodiversity.

This involves a set of practices in which the use of external inputs is minimised. Synthetic pesticides, chemical fertilisers, synthetic preservatives, pharmaceuticals, GM organisms, sewage sludge and irradiation are all excluded. Interest in organic agriculture has been boosted by public concern over pollution, food safety, human and animal health, and by the value set on the environment.

In developed countries, like Germany, government subsidies have helped to make organic agriculture economically viable.

In the late 20th century, the total area of organic land in Europe and the United States tripled, albeit from a very low base. However, many European countries have ambitious targets for expansion, with the result that Western Europe may have around a quarter of its total agricultural land under organic management by 2030.

Large supermarket chains such as Tesco, Wal-mart, Asda, etc have bought into this recent organic explosion, compelling them to invest more as potential demand far outstrips supply. In many industrial countries, sales are growing at 15% to 30% per annum. The progress of organic agriculture is fostered by certified inspection agencies on clearly defined methods.

Organic agriculture offers many environmental benefits. Agrochemicals can pollute groundwater, disrupt key ecological processes such as pollination, and harm beneficial micro-organisms and cause health hazards to farm workers. Modern monoculture using synthetic inputs often harms biodiversity at genetic, species and ecosystem levels. The external costs of conventional agriculture can be substantial.

In contrast, organic agriculture sets out to enhance biodiversity and restore the natural ecological balance. It encourages both spatial and temporal biodiversity through inter-cropping and crop rotation, conserves soil and water resources and builds soil organic matter and biological processes. Pests and diseases are kept at bay by crop association, symbiotic combinations and other non-chemical methods.

Water pollution is reduced or eliminated. Although yields are often 10% to 30% lower than in conventional farming, organic agriculture can provide excellent profits. In industrialised countries, consumer premiums, government subsidies and agro-tourism boost incomes from organic farms. In developing countries, well-designed organic systems can give better yields, profits and returns on labour than traditional systems.

Organic agriculture also has social benefits. It uses cheap, locally available materials and usually requires more labour, thereby increasing employment opportunities. This is a considerable advantage in areas where or when there is a labour surplus. By rehabilitating traditional practices and foods, organic agriculture can promote social cohesion. Certain policy measures are essential for the progress of organic agriculture to continue.

Support for agriculture is increasingly shifting from production goals to environmental and social goals, a trend that could favour organic agriculture. Agreed international standards and accreditation are needed to remove obstacles to trade.

Other key areas to look at include:

- Improved marketing strategies.
- Improved agro-forestry systems.

- Improving irrigation and water harvesting systems enables farmers to produce more crops per drop, and multiply their incomes through high-value products.
- An improved seed system/use of improved crop varieties.

Livestock production would also need a significant boost to meet demand as they not only supply meat, dairy products and eggs, but also wool, hides and other industrial goods. Livestock production can be closely integrated into mixed farming systems as the end-users of crop by-products in addition to acting as sources of organic fertiliser, ploughing and transport. Selection and breeding and improved feeding regimes, could lead to faster fattening and larger animals. Practices would involve routine hormone therapy, artificial insemination through biotechnology, a deeper understanding of animal genetic make-up for improved disease control, adaptation to environmental stresses and increased production. Intensive systems of stall-feeding can be expected to continue and accelerate in areas where land availability is scarce, leading to less soil damage and faster fattening.

A continued shift in production methods can be envisaged, away from extensive grazing systems and towards more intensive and industrial methods. Mixed farming, in which livestock provide manure and draught power in addition to milk and meat, still predominates for cattle. As populations and economies grow, these multipurpose types of farming will tend to make way for more specialised enterprise.

4. Market, Financial Issues and Criteria

Attracting substantial finance and investment is a prerequisite for scaling up the development of biofuels internationally. The challenge is to introduce the right policy frameworks and financial tools to enable biofuels to achieve their market potential.

Capital flows to the market environment which demonstrates strength, clarity and stability: That environment must be specific enough to improve the bankability of projects and provide conditions for steady market growth. Rules and incentives need to be stable and sustained for a duration that reflects the financing horizons of the projects.

It is important to note that at the early stages of development of the biofuels – or any other - technology, supplementary incentives that support technology innovation are required in order to provide an environment that rewards entrepreneurial activity.

A framework which fosters local ownership, production, processing and use can enhance commitment to biofuels. Development of strong domestic credit markets is a necessary element in the financing chain to enable businesses to access finance for their activities. This requires both capacity building and improved information exchange.

At present, there is no robust global market for biofuels, only a few weak regional markets. There are two reasons for this. First, an international technical standardization of biofuels has not yet taken place. Second, protectionist policies developed in producing nations have prevented world-wide adoption of competitively priced biofuels.

Generally, the development of biofuels on a global scale makes a lot of sense. So what then can and should be done about the diversity of source types available for biofuels and the diversity of geographical assets (e.g. Brazilian sugar cane, American corn, India’s cassava, Africa’s sorghum, Europe’s wheat, etc)? How will Brazil’s sugar cane be used in the United States or how will African sorghum be used in Europe or how will American corn be used in Asia?

Petroleum price volatility

During the era of oil dominance, the price of oil has always been of great interest. The link between the early economic development and the access to energy has given the price of oil a great importance on a global scale. More recently, given a better understanding of the consequences of climate change, a new dimension of the oil price has emerged.

Petroleum is a highly concentrated energy resource, and the world’s current transportation systems are almost completely dependent on it. As a result, the world economy is (or could be) at risk if oil supplies are disrupted in any of the relatively few countries that are significant oil exporters.

As a result of concentrated wealth, social tensions, and inadequate political institutions, many of these countries are less-than-secure suppliers of the world’s most vital commodity. Biofuels promise to bring a much broader group of countries into the liquid fuel business, diversifying supplies and reducing the risk of disruption.

Since biofuels can practically be produced in most regions of the world, the risks inherent in transporting them over long distances will be reduced, too. In the long run, this is likely to help stabilize fuel prices.

As for any other commodity, the oil price is fundamentally based on two drivers: supply and demand. The history though, has proven that not only these two drivers have an impact on the price.

A range of other factors, including the US dollar exchange rate, oil inventories, refinery capacity, geopolitical and other unexpected events, human psychology and behaviour, availability of substitute energy sources, and developments in the financial sector, all have an impact on the oil price.

Typical features of oil business are its highly technological and complex nature, with long term investment commitments, cyclical developments, high fixed and low variable costs.

The supply and demand are the key factors. Over the years, supply disruptions or rapidly changing demand fluctuations have affected the oil price significantly. In 1974 and later in 1978, the use of oil as a part of the political agenda had significant impacts on the oil price. The increased prospecting and later production of oil in other regions, such as the North Sea, Alaska and the Mexican Gulf ensured a long period of increasing production capacity.

Combined with a decreasing demand after the second oil crisis in the late seventies, this led to a long period of large overcapacity and low oil prices. The unexpectedly quick increase in demand from Asia, China in particular, around 2004 started a price rally that was discontinued only by the crash in the global economy in 2008.

The US dollar exchange rate, given its dominating role in oil transactions globally, will have an immediate effect on the oil price. This price effect will of course vary from one country to another as a consequence of its exchange rate against the dollar. Nevertheless the dollar oil price will rise when the trade weighted dollar exchange rate falls, and vice versa.

Other factors contributing to a volatile oil price include psychological factors as well as inventories. The mere perceived risk of shortages in the market is sometimes enough for price increase.

During the first years of the 21st century production capacity was close to balancing the demand. This made the market nervous due to the insufficient spare capacity, in case of a major incident. Inventories are also of importance. Among other things they give a clear signal about the supply situation. Increasing inventories normally show that the market is well supplied and that the risk of a supply crisis is low and vice versa.

The difference between the full cost barrel for the highest marginal production and the lowest marginal variable cost is significant. The estimate of US$80 per barrel for oil sand investments and other front edge production technologies is not out of the ordinary, compared to the marginal variable cost of less than US$10 per barrel.

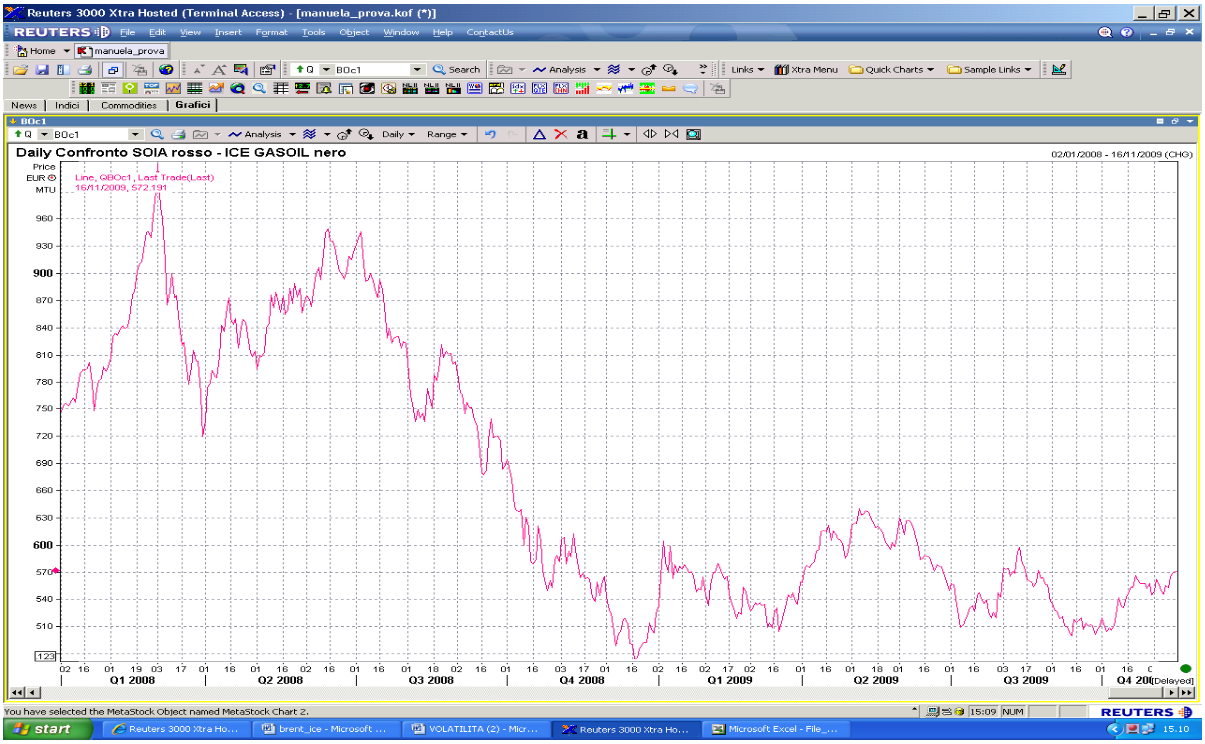


Figure 1: Soybean price development 2008-2009

The role of the financial sector in oil price setting has been broadly debated during the 2008 economic crisis. OPEC has stated very clearly that it blames the financial sector for the strong volatility in the market during 2008. Others argue that the financial sector can never influence such a market to the extent that it drives the price.

Substitutes as well as the general price elasticity of the product are also of concern. The energy market has a number of border areas where the consumer could chose between different types of energy for the same application.

Prices and price development trends of, for example, coal, natural gas, biomass, biofuels and other primary energy resources have an impact on the oil price and vice versa. The price elasticity of certain products within the petroleum sector is extremely low. Aircrafts, for instance, must today use a globally standardised product and there are no substitutes available.

Biofuels as an Alternative to Oil

Despite potential future supply constraints, the recent global economic slowdown forced the price of oil down to the point where it seriously undermined the expectations of continuously high oil prices. In July 2008, when the oil price was US$147 per barrel, it was unthinkable that within six months it could fall back to US$30.

Such volatility undermines investor confidence and the expectations that future supply and demand constraints will push oil prices to a point where alternatives, like biofuels become and remain lucrative. Consequently, alternative fuel projects become less attractive to the financial markets because they require large cash commitments.

Vegetable Oil Markets' Volatility

The high volatility which has always been a feature of financial markets, has been growing even stronger in the past few years and it has gradually spread towards commodities markets.

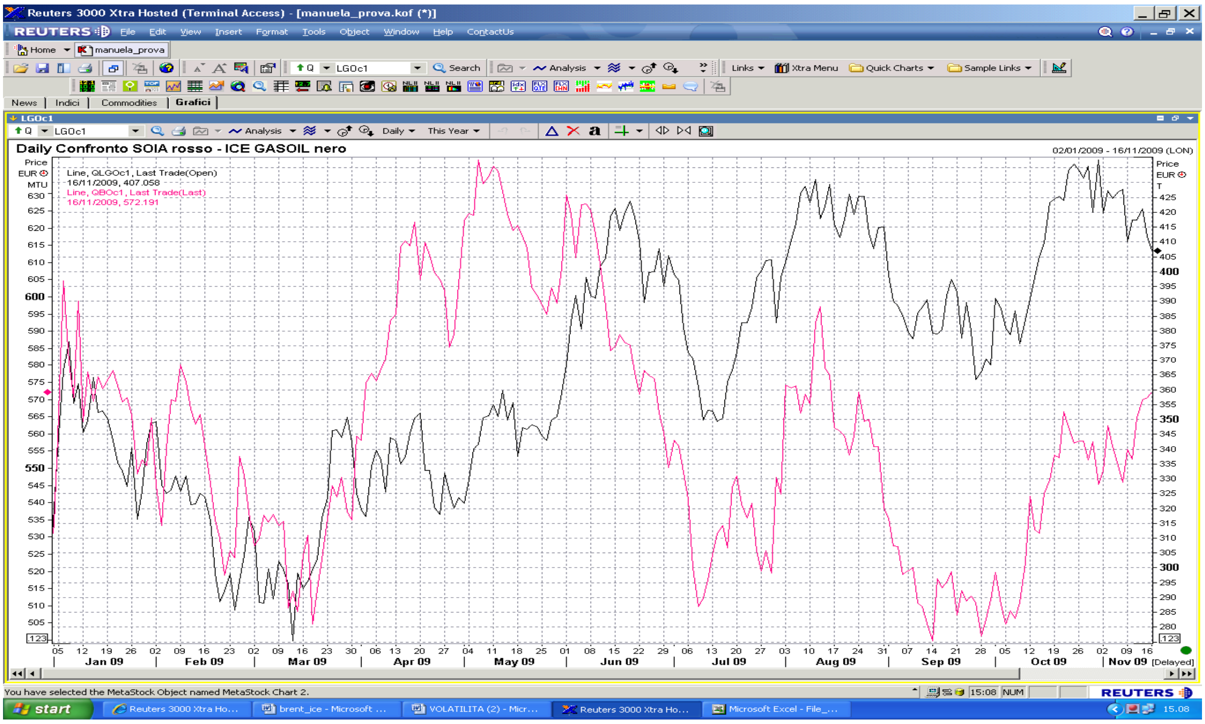


Figure 2: Soybean oil (red line) and London ICE gasoil (black line) prices

Vegetable oil markets and raw metals have been always lead by physical drivers and real factors and the prices have been set by the match between real supplies and demand. Moreover, vegetable oil price has also been influenced by the weather conditions which have a significant effect on harvests.

Lately, the trend of vegetable oils prices has been strongly influenced by speculation and this has resulted in an non-linear trend, hardly connected to the real economy.

Today, careful monitoring of vegetable oils prices is essential for biofuels producers. It has become absolutely necessary for them to understand the contextual aspects which have an impact on oil and vegetable oil prices. The oil price influences their sales since it affects biofuels prices, while vegetable oil prices influence the supply side since they affect the price of raw materials.

Figure 2 clearly demonstrates the spread between Soybean oil price (red line) and London ICE gasoil (black line). This could be considered as a proxy of the trend for the mark up by biofuel producer/seller. There are some periods in which the price of raw materials outpaces that of gasoil causing a contraction of the mark up and the risk of a loss.

Examination and implementation of hedging strategies is crucial to ensure profits. There are numerous financial instruments which can mitigate risks. On the supply side, there is the possibility to establish contracts defined as “open” which offer traders the opportunity to fix the vegetable oil price in a period of low prices, while on the sellers’ side, it is possible to negotiate derivatives that offer protection against the downturn of oil price. Prudent hedging strategies have been of key importance during the first half of 2009.

Financial Requirements for Developing Commercial Scale Biofuels Production

There are two ways to pay for the development of a commercial scale refinery hrough financing or cash. Before considering funding options, it is necessary to understand the demand for biofuels. All references below are in terms of barrels of oil equivalent (boe) and not in tonnes.

Demand for Biofuels (also known as off-take)

At present, demand for biofuels has mainly been a function of government regulations and mandates. The actions taken by governments have been necessary to develop the demand for biofuels.

Their supportive policies and regulatory actions will be needed going forward if biofuels are to contribute on a considerable scale to transportation fuels mix. If regulatory support were withdrawn, it is not at all clear that biofuels would be able to compete with the current oil derived transport fuel products.

In order to build a commercial scale biofuels refinery it is necessary to understand the role of the off-take risk. If a developer of a biofuels refinery determined to pay cash for the facility it is necessary to know the demand of the product. As such, off-take analysis is performed by developers to ensure that adequate return on investment is possible for the investment. Small commercial facilities have been built without financing, but most, if not all, major facilities required financing.

To finance a commercial scale biofuels refinery the off-take risk is of greater significance. For example, if a production facility were built on speculation, the expected financial risk would be much greater and the cost of capital would increase. At present, as a result of the 2008-2009 financial crisis the financing of a speculative biofuels production facility is almost impossible. However, if “off-take” contracts were signed guaranteeing that buyers would purchase the biofuels, financing would be much easier.

Financing Commercial Scale Biofuels Refineries

The financial crisis of 2008 and 2009 has made developing biofuels refineries more difficult. To understand the issues related to financing commercial scale fuel facilities other fossil fuel and biofuels based alternative fuel facilities have been examined.

In 2007, a project finance team was assembled for a 5,000 barrel a day coal-to-liquids project to be built in the United States. The expected capital expenditure was US$800 million or US$160,000 per barrel per year.

Currently a 35,000 to 53,000 barrel per day project is in the planning stage for a different coal-biomass-to-liquids project in the U.S. The expected capital expenditure is US$5 billion or US$94,000 to US$143,000 per barrel.

In Qatar, the 120,000 barrel per day Shell Pearl gas-to-liquids facility final costs are expected to be US$18 billion or US$129,000 per barrel. Finally, the Abengoa Madison bioethanol facility in the United States is expected to produce approximately 5,480 barrels a day and cost US$200 million or US$37,000 per barrel.

Although there is a large capital expenditure difference between the fossil fuels based alternatives and corn-based biofuels, the capital costs are still significant.

Former U.S. Secretary of Energy James Schlesinger has stated on several occasions that actual CAPEX costs are more valuable indicators than projected CAPEX costs because the best laid plans are ultimately changed by real circumstances. Therefore, the analysis below is based on published data of real projects and not planned projects.

Using the CAPEX rates of the Pearl GTL (high cost example) and the Abengoa Biofuels facilities (low cost example), a 100,000 barrel a day plant for GTL would cost US$13 billion; for the biofuels facility it would cost US$3.7 billion – these figures do not factor input price increases, commodity availability or cost of money calculations and only represent 1/8th of one percent of displaced oil usage. Although, other fuels sources have different capital costs, the Pearl and Abengoa projects were used to provide a high and low cost case study.

Given that the capital costs for Abegoa are US$3.7 billion, in the current financial environment, financing of this magnitude would require the loan to be syndicated by investment banks in an effort to diversify risk for all lenders.

Given the large CAPEX requirements and the high cost of money, securing syndicated loans is quite difficult without certainty that demand for your alternative fuel is guaranteed.

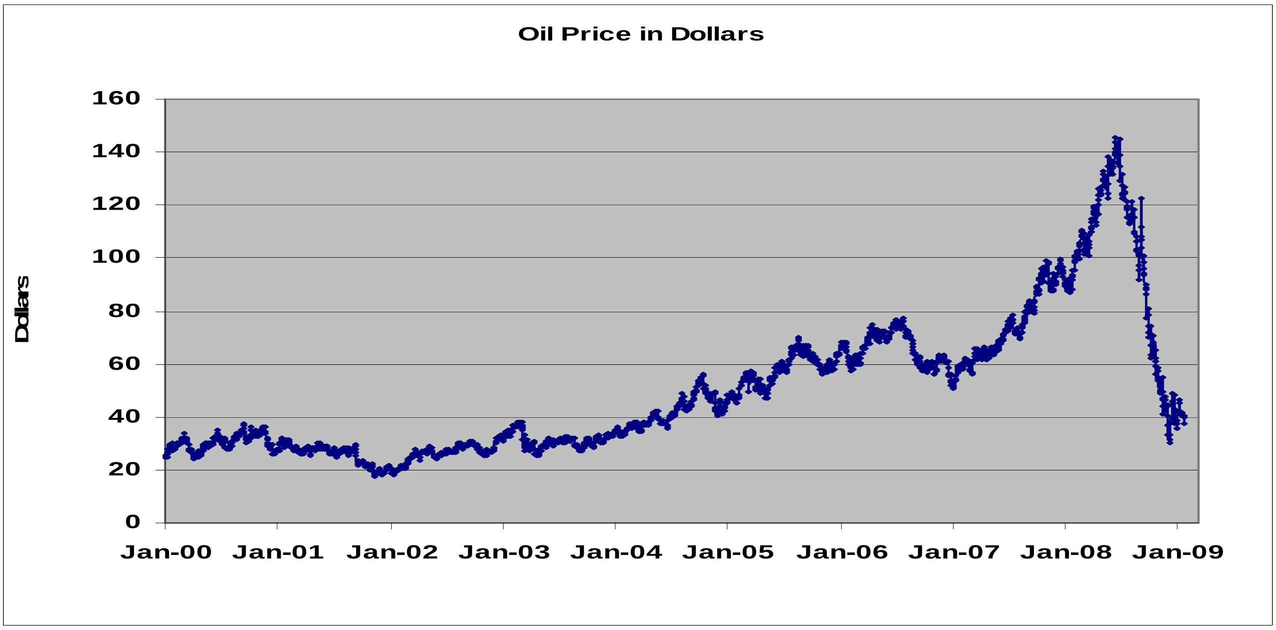
Further, oil price volatility has undermined the interest of investment banks to risk placing capital into biofuels facilities unless government loan guarantees and mandates are in place.

Using Cash for Developing Commercial Scale Biofuels Refineries

Paying cash for the development of commercial scale biofuels refineries has been done in cases where production was quite small in relative terms to existing oil refineries. Going forward, it is unlikely that biofuels developers will develop production facilities unless governments continue developing supportive regulatory actions.

Production of Biofuels

- In 2007, Brazil produced over 4.5 billion gallons of sugar-based bioethanol (294k bbl/d refined equivalent).
- In 2007, the United States produced over 6.5 billion gallons of corn-based bioethanol (424k bbl/d refined equivalent).
- In 2008, the United States produced an estimated 250 million gallons of biodiesel (15.5k bbl/d).
- In 2008, Europe produced 1.5 billion gallons of biodiesel (93k bbl/d)



Although the world markets recovered to some extent by late summer 2009, the world-wide economic distress that began in 2007 emphasises the significant risk involved in developing alternative fuel projects, including biofuels, due to the possibility that falling oil demand can cause oil prices to plummet. The result of this most recent economic contraction caused credit to tighten and banks to deleverage. The consequence of the tighter credit markets and deleveraging of banks meant that the financial health of corporations had become, at least for a period of time, gauged by "free cash flow" and "low debt" metrics.

The volatility in oil prices from July 2008 to August 2009 (US$147 to US$30 to US$70) has made it more costly for energy companies to access the credit markets.

Further, oil and natural gas price declines have led energy companies to scale back investment in new projects. Even the strongest oil companies, like Exxon and Shell, have scaled back development of some oil projects to ensure that they can adequately meet economic consequences of the worldwide slowdown.

The lack of investment by the oil companies is likely to lead to future oil supply constraints, which will push oil prices higher, in time significant debt, government subsidy, loan guarantees, supportive regulation, climate-change legislation and/or higher prices than US$30 per barrel.

The chart below shows the extreme price volatility of oil. Two recently released reports addressing the role of futures trading and speculation in the price of oil come to conflicting conclusions. The Masters' Report, authored by hedge fund manager Michael Masters, released in August 2008 used data available from the Commodities and Futures Trading Commission (CFTC).

The report indicated that institutional investors poured US$60 billion into oil futures from January to May of 2008, thereby causing a steep increase in the oil price. Masters went on to saying that "we have clear evidence that fund flow pushed prices up and the fund flow pushed prices down."

At the same time, the CFTC issued their own report on 11 September 2008 and stated, "While oil prices rose during the period of 31 December 2007 to 30 June 2008, the activity of commodity index traders during this period reflected a net decline of swap contracts as measured in standardized futures equivalents."

In essence, the CFTC indicated that actual level of investment in futures trading declined during this period. The CFTC also stated that they lacked sufficient data to understand the role of the oil futures market on oil pricing. Therefore, it can be concluded that because the Master's report uses data from the CFTC, it does not have the evidence to support the claim that fund flows pushed prices up and down.

At present, the CFTC lacks the specific data for any meaningful conclusions on the role of futures trading in the oil price movements. For example, the CFTC collects data on the number of open futures contracts, but does not collect the data on the number of contracts that are held through expiration. Upon expiration, the contract holder is obliged to provide or receive 1,000 barrels of oil.

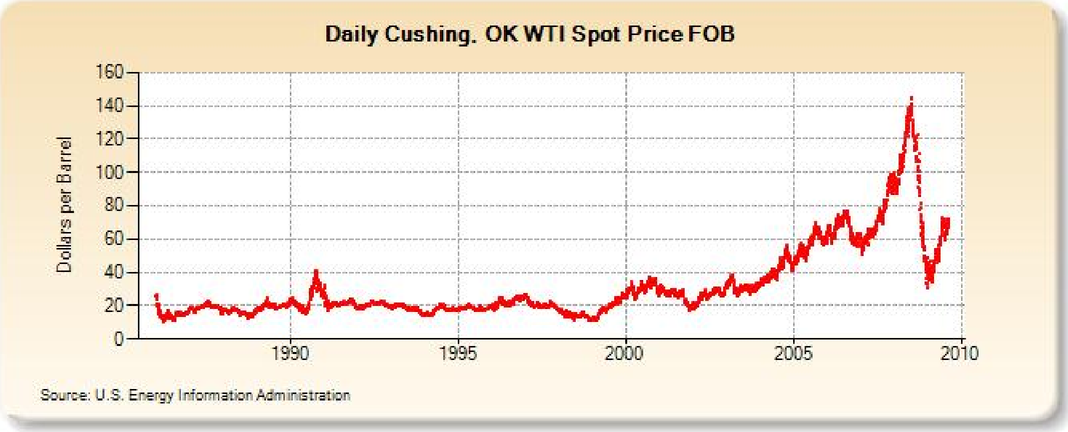
Those who hold contracts through expiration are trading the "real commodity" and not just a "paper contract." Such data is necessary for understanding of the actual fundamentals of oil trading on the futures exchanges and the "velocity" of the paper contracts.

The CFTC Report also recommends that a new data collection division be established to help collect more specific data.

Geopolitical Events

It is fairly obvious that oil prices are influenced by geopolitical events.

- On 6 June 2008, when bullish sentiment for oil was high on Wall Street, the Transportation Minister in Israel stated that conflict with Iran was inevitable - oil prices increased by ten dollars.
- On 25 June 2008, militants in the Niger Delta called off their unilateral ceasefire and resumed hostilities - oil prices increased by five dollars.
- On 8 August 2008 when Russia and Georgia entered in the military and political conflict where the Baku-Tbilisi-Ceyhan pipeline carries one million barrels of oil per day - oil prices declined nearly by five dollars.



- On 13-16 September 2008 Nigerian militants attacked oil facilities throughout the Niger River Delta causing nearly 115,000 barrels a day of crude to be "shut-in" - oil prices fell from US$101 to US$91. It is likely that market sentiment becomes a factor in geopolitical events which lead to volatility in oil prices. Given these challenges, it is difficult to quantify the impact of geopolitical events on the price of oil. Yet, it is obvious that a disruption of Saudi production will have a greater impact on world prices than the disruption in Nigeria.

Oil Producers

Although the oil production figure helps establish the price, concerns over OPEC and non-OPEC supply capacity also influences the market. During the oil supply shocks of the 1970s excess capacity in Saudi Arabia was over 18%, in 2007, it was considered less than 3%.

Given the economic crisis at the end of the 2008-2009 and falling demand, spare capacity numbers are hard to determine, but they are probably greater than 3%. Figures related to oil supply are hard to find. The lack of transparency in oil supply figures is due to the unwillingness of oil producers to share oil supply data and this makes it difficult to define the real relationship between oil supply and volatility of oil price.

In general oil producers, IOCs and NOCs, sell oil directly to refiners and distributors. The price at which these contracts are executed depends upon the spot price of oil, the oil futures market and specific business relationships. Oil producers also engage in selling supply on the futures market to lock in prices and to hedge against price volatility.

Generally, contracts are established to provide maximum revenue for producers in their relationship with distributors and refiners. It has been suggested by energy industry that oil producers become price-takers in a price increasing environment and price-setters in a price decreasing environment.

Supply and demand fundamentals

Debates rage over peak-oil theories. This study leaves this argument aside. However, it is unclear how accurate supply projections can be made since there is a lack of transparency in oil reserves data and data provided by oil producing countries. Without independently audited data of oil producing countries, an understanding of supply and demand fundamentals and their impact on oil prices is almost impossible.

Oil Price as a Risk to Investors

At present, all publicly announced plans to develop commercial scale alternative transportation fuel facilities in the United States require private financing. According to bankers interviewed for this study, “off-take” risk needs to be clearly understood. To interpret, investors need to understand who will buy the fuel and for how much.

If the facility is being built on the speculation that transportation fuel demand will absorb the alternative fuel being created, then investors will study the oil, gasoline and distillate markets to understand the supply and demand fundamentals.

All respondents stated that fear of an oil supply glut will cause a low oil price, which in turn will undermine the alternative fuel profitability, is the single greatest risk in these projects. If the project has no long-term contractual buyer of the fuel, then investors demand higher returns for putting their capital at risk. At present, no proposed project – other than bioethanol projects because of MBTE regulation, subsidy and the renewable fuels mandate of EISA 2007 – has a long-term contracted buyer or secure demand.

Biofuels Investment and Climate Change Regulations

Calls for global carbon regulations are growing. The Conference of the Parties 15 (COP15) held in Copenhagen in December 2009 was expected to reach a global far-reaching agreement to replace the Kyoto Protocol. This did not happen, although certain progress has been achieved on a number of points.

Further, the debate on climate change is likely to produce regulations world-wide that will encourage and/or subsidize biofuel investments. To help overcome the risk of oil price volatility undermining investment in biofuels, regulators will need to enact particular policies to encourage investment into biofuels.

Production mandates can provide a floor of production for biofuels thereby removing the “off-take” risk – this has been done in many countries. Loan guarantees and subsidy are other tools available to regulators.

In general, as an alternative to oil, biofuels is not a safe investment today. As a potential help to climate change regulation, biofuels looks like a good investment.

5. Standards, Policies and Regulation

International Standards for Liquid Biofuels

Among the factors currently limiting the development of regional and global biofuels markets, the lack of comprehensive and generally adopted international standards is most important.

The International Standards Organisation (ISO) is currently working on developing certain biofuels standards, and the outcomes of this effort are eagerly awaited. The subsequent International Standards will help the broad development of biofuels worldwide.

The proposal for ISO standards on liquid biofuels has been reviewed by ISO members and their stakeholders, and follows on the work done under the International Biofuels Forum (IBF), a tripartite group involving Europe, USA and Brazil.

In 2007, the IBF circulated a white paper: *Internationally Compatible Biofuel Standards* which, as the title suggests, focused on the need for the existing standards to be compatible with each other. The IBF does not, in the paper, indicate whether single, harmonized International Standards are possible or needed by the market.

ISO has established a committee on liquid biofuels under ISO/TC 28/SC 7 and the group met for the first time in January 2009 in Brazil. The discussions at the meeting served to confirm a number of conclusions of the IBF white paper.

In this respect, ISO/TC 28/SC7 has focused on a role of information collection and monitoring he work of other standards bodies. As this is not the usual objective of an ISO committee developing International Standards, this role may be reviewed in the future.

To address the need for common sustainability criteria, the ISO members from Germany and Brazil (DIN and ABNT respectively) circulated a proposal for a new Project Committee to develop a single ISO standard. The voting results among the ISO members were successful and a committee was established in this area. The Committee's work is at an early stage, and so far the following has been agreed:

Scope
Standardisation in the field of sustainability criteria for production, supply chain and application of bioenergy. This includes terminology and aspects related to the sustainability (e.g. environmental, social and economic) of bioenergy.

- Inventory of initiatives;
- Terminology;
- Greenhouse gases;
- Environmental aspects;
- Social aspects;
- Economic aspects;
- Verification and auditing;
- Indirect effects.

Classification

In a simplified manner, biofuels can be sub-divided into two large categories: biodiesel and bioethanol. This division puts forward the key properties of the two products. On one hand biodiesel (which replaces diesel in cars) is produced from oil rich plants (e.g. rapeseed, sunflower, algae, etc.) by mixing the vegetable oil (90%) with methanol (10%) in the process called trans-estherification; on the other hand bioethanol (which replaces petrol in cars) is also known as an alcohol and is produced through the fermentation of sugars from cereals (wheat, maize, etc.) or sugary feedstocks (sugarcane, sugar beet). (See ANNEX 6 for more detail)

New production techniques or pathways have been recently developed. These are sometimes referred to as “second” generation biodiesel: Hydro-treated vegetable oils (HVOs): New technologies provide for the hydrogenation of vegetable oils (HVOs) and animal fats into a paraffinic biodiesel, which presents near identical chemical properties with conventional diesel. Although hydro-treated vegetable oils in Europe are produced in free-standing facilities, this process can build on existing oil refinery infrastructures. To avoid any confusion with processes used in the food industry sector, the term « hydro-treatment » is preferred to « hydrogenation».

Biomass to liquid (BTL) is a multi step process to produce liquid biofuels from biomass. Contrary to currently used biodiesel pathways (FAME and hydro-treated vegetable oils and fats), the Biomass-to liquid process aims at using whole plants (biomass), including agricultural and forest residues.

The so-called “Fischer-Tropsch” technology, which is an integral part of the BTL process, is an advanced biofuel conversion technology that comprises gasification of biomass feedstocks, cleaning and conditioning of the produced synthesis gas, and subsequent synthesis to liquid (or gaseous) biofuels. Originally, this process was used for the production of liquid fuels from coal (CTL) and natural gas (GTL). The CTL, GTL and BTL production pathways are usually referred to as “XTL” fuels.

Biodiesel from animal fats and used cooking oils UCOs: Many European producers also use recovered vegetable oil and animal fats from food processing as it is a readily available waste product and produces a biodiesel with extremely beneficial greenhouse gas savings. Several of the biggest biodiesel producers in Europe are agricultural producers who add value to their oilseed products and processing capacities by converting oil to biodiesel, similarly many are involved in the oleo chemical industry as biodiesel production produces glycerine suitable for the cosmetics and pharmaceutical industries. Biodiesel production also results in increased availability of oilseed cake used for protein in animal feeds.

Certification

Certification is the practical implementation of the standard or of the principles and criteria that are aimed for. This step requires a tracking method and a labelling process and it is known as the **certification** of the product under assessment. Certification is the practice that implies third party assessment of the management procedures with respect to a certain standard.

A good or service that is required to comply with a certain standard has to pass through the certification procedure. Here, the product will be translated from the pool of unidentified goods/ services into the smaller category of labelled goods. The product will be recognizable and its compliance with the standard in question will be indubitable.

Certification is the final step in the chain. However in order to fully develop the certification phase, one should discuss the previous segment, which is the traceability or the chain of custody.

Certification initiatives

Certification confirms practical implementation of the standard or the principles and criteria that should be achieved. This requires a tracking method and a labeling process, and it implies a third party assessment of the procedures with respect to a certain standard.

So far, certification exercises have been completed and implemented with success in the following fields: agricultural (crops, vegetables, fruits, etc.), forestry or electricity. In the biomass sector, several initiatives have been created for the certification of bio-energy or biofuels.

Technical Standardization

Although major refiners like ConocoPhillips, British Petroleum/BP and others blend currently biofuels into transportation fuels like gasoline and diesel, this is not supported by sufficient technical standardization which would allow and facilitate robust growth of biofuels on a global scale. Large, well-established refiners have the wherewithal to blend different source types into current transport fuels, but it typically requires new additions to traditional petroleum refineries that are expensive.

> Establishing biofuel technical standards would, over the long run, help reduce capital expenditures for large and small refiners, benefit new participants in the refining business, and help capital markets develop more specific products for syndicating debt for biofuel refining.

The application of certification schemes requires careful consideration of all factors involved. Early in the conception and the development stage, it is crucial to develop or to follow sound sustainability principles and criteria. Certification work is often criticized for lacking substance and structure and the following main issues have been identified:

- scope inconsistencies
- implementation inconsistencies
- market failures
- costs barriers
- trade limitations.

Standardization of sustainably grown biomass for biofuels

Since the production of biofuels in general is so strongly related to agricultural activities, the European production in particular follows the EU Common Agricultural Policy that governs all environmental standards of agricultural production.

Therefore the sustainability of European biodiesel and bioethanol is guaranteed by the Cross-compliance rules followed by the

European Farmers and by all social and economical standards of developed economies.

As a result the European Production of biofuels does not contribute to deforestation or land degradation due to existing management practices and stringent national environmental legislation in the European Member States. Additionally, agricultural potential in new member states is finally becoming productive under the Common Agricultural Policy and European or private investment.

A need for standardization of sustainable production of biomass

Although biomass production in Europe rightfully claims the highest sustainability practices in the social, environmental and economical areas, a level playing field must be created at a planetary scale.

Secondly, it is senseless to standardize practices only in one sector of agriculture, where in fact the major sustainability concerns are omnipresent. Thirdly, major risks are present or foreseeable in the future from a sustainability perspective. These risks can be found in different locations and present local/regional specificities.

Finally, it is important to consider the different legislations, the different regulatory frameworks but also the numerous voluntary initiatives that govern the biomass applications, especially for the biofuels end use.

Against this background, clear universal rules have to be defined for sustainable practices. At the same time the rules have to be applied for all biomass production horizontally, regardless of the final use. If this key point is disregarded, then the whole purpose of sustainability standards is lost. If only a small part of the production of biomass is being done in line with the sustainable practices and the rest is done through deforestation, biodiversity losses and in poor social conditions, then sustainability is nothing more than a market failure.

In this context, one optimal approach is to harmonize the minimum binding requirements in the field of biomass for energy and to horizontally apply these requirements to all the biomass production regardless of the end use. This approach should base itself therefore on the requirements already in place at EU level and in USA, Brazil, Malaysia, Indonesia, Argentina, etc.

The market will therefore incline the balance towards a meta-standard that follows the legislation pathway or towards a more stringent voluntary standard. In the field of biofuels in Europe, players face an obligation to market the product and the legislation has already set very high sustainability principles. As a result, there is no clear reason why players should set the sustainability threshold even higher. They already face the highest possible challenges compared to any other field of activity and they embrace these challenges courageously.

Finally, the market players will determine the relevance of different standards. They will decide upon their individual needs (imports/exports into/from different countries, marketing purposes, costs etc.).

It is crucial to remember that costs are the main drivers for all economic activities which will include now more and more corporate and social responsibility (CSR), and sustainability aspects. In a cost and CSR-driven economy, the role for voluntary higher standards will remain clearly mitigated. Defining the sustainability criteria for biomass for energy applications is a complex process which has crucial market implications. In the end, if not designed correctly, sustainability and certification schemes will undoubtedly trigger significant market disruptions.

The state of the art of sustainability research for biomass for energy shows a complex framework in which voluntary and mandatory schemes co-exist. This framework must only be considered as a snapshot. New initiatives and certification schemes are announced regularly while the process of developing knowledge in this field will endure.

However, while analysing the features of existing sustainability initiatives and the prospects for the future ones, it is important to consider all limitations in implementation, the drawbacks and the risks involved.

Risks and limitations in development and implementation of certification schemes

The application of certification schemes requires careful consideration of all factors. Early in the conception and development stage, it is crucial to follow sound sustainability principles and criteria. Parallel certification work is often criticised by stakeholders for lacking substance.

The main critiques or limitations brought forward so far are as follows:

- **scope inconsistencies**: sustainability principles, criteria and indicators are inadequate; not all stakeholders involved in the sustainability process;

- **implementation inconsistencies**: monitoring and verification systems are inadequate or even impractical for on-site auditing;

- **market failures**: the proliferation of labels and certificates undermines the substance of sustainability initiatives; consumers cannot make informed choices;

- **costs barriers**: overburdening small producers leads to a market exit; the implementation of any scheme adds a cost to the overall production; when an individual operator is bound to comply with multiple schemes, he will be unable to cover costs;

- **trade limitations:** a sustainability and or certification system should not limit trade; however it should follow the legislation in force.

Infant Industry Support

It is usual for countries to consider policies to support infant critical industries. Biofuels is both an infant industry as well as a critical industry in many countries. With the oil price volatility of the past few years, many countries have made energy security arguments while others claim that environmental demands require the development of biofuels and many countries claim both. Regardless of the justification, supportive policies for infant industries are used to meet domestic political realities.

These policies, in many ways, are helping develop the regional markets for the biofuels industry, but if maintained for too long, they can undermine the development of a global market for biofuels as a fungible commodity with petroleum. This would lead to less protection, not more.

Brazilian sugar-based bioethanol and American corn-based bioethanol provide an excellent case study for how these policies work. In the United States, tariffs have been placed on imported bioethanol.

This was designed to help the American corn industry develop bioethanol to meet domestic demand. Many arguments were made in the United States for why these tariffs should be established, and the two loudest were "energy security" and the "buy American" mantra.

In Brazil, where sugar-based bioethanol can be produced and shipped for less than American corn-based bioethanol, this looks like a punitive tariff directed at Brazil to keep them from entering the U.S. market. In many ways this is accurate, but it is not the whole story. The United States is attempting to protect an infant industry in order to have domestic capacity for production of fuels which helps strengthen economic and energy security.

More importantly, the tariffs allow for the infant industry to gain strength during the time that it helps develop demand. Ideally, the development of the corn-based bioethanol market will reach a point where demand grows past domestic supply capacity.

It is at this point, where supply constraints will encourage policy makers to open up the market to foreign suppliers. This would then allow those countries who have an absolute-advantage[1] to become global suppliers.

The best example to help explain how the biofuels market can develop past the infant industry policies is the history of the oil market. As oil was discovered in the Middle East and Southeast Asia, countries like the United Kingdom and the Netherlands established preferential import agreements with companies such as the Anglo-Persian Oil Company (British Petroleum/BP) and Shell, respectively, in an effort to protect national interests.

These policies helped develop the infant oil market in the U.K., the Netherlands, and the whole of Europe. Eventually, the global market grew because other countries engaged in similar practices until the markets became more developed and sophisticated. Once the markets matured the preferential policies of the U.K., the Netherlands and others gave way to a more robust global market.

Most important is that industry leaders and policy makers understand that supportive infant industry policies help develop a marketplace on a regional basis. Without these policies it is unlikely that these regional markets would develop and these are a prerequisite for a global market.

Countries like Brazil have an absolute advantage as they can produce biofuels from sugar cheaper than biofuels can be developed in other countries, and that is good for the world. Brazil's climate and tropical conditions allow it to be to biofuels what Saudi Arabia is to oil.

At the earliest opportunity, those countries that have in place infant industry supportive policies to help their young biofuel industries should begin to allow room for imports from countries that can provide low priced quality biofuels. Such an approach would help regional markets mature into global markets and allow for biofuel consuming nations to benefit from lower prices and greater diversification.

Encouraging Comparative Advantages

Countries that have an absolute advantage in biofuels production should encourage the development of regional markets and infant industries in other countries. Although counter-intuitive, large supplier countries, stand to gain the most as the world grows from regional markets to a global market place for biofuels.

Further, these countries should recognize that they can be instrumental in the development of biofuels world-wide by providing technology and intellectual capital to other countries that would like to transform unused arable land into fuel producing crops.

As supplier countries build these markets they can position themselves through cooperative agreements to provide product at lower costs through an already established “down-stream” distribution system. This downstream distribution system is developed on a regional basis and that provides another incentive for supplier countries to help other countries develop regional biofuel capacities.

Allowing Room for Absolute Advantage

As decision makers establish different policies to encourage and incentivize the development of biofuels, they should consider how they can best provide energy, economic and environmental security over the long-term. This means that infant industry policies should make room for imports from countries that can provide technically adequate supply for lower costs than domestically produced biofuels.

This, of course, would also help importing countries lessen dependence upon petroleum by diversifying the source of type of the fuel. Finally, allowing for imports of biofuels in consuming countries would help establish a global marketplace and reduce costs. This does not have to come at the expense of domestic production as it may be determined beneficial to maintain domestic support and open markets.

The EU Biofuels Policy And Regulatory Landscape

In a strive to alleviate climate change related environmental degradation as well as the increasing scarcity of conventional energy sources, the European Commission set in 2003 the basis for the promotion of the use of renewable energy in transport. This legislative act was entitled the “Biofuels Directive”[2] as it mainly laid down indicative targets[3] for biofuels use in transport in the European Union from 2005 up to 2010. (See ANNEX 7 for more detail)

Concomitantly the European Commission laid down a comprehensive fiscal framework taking into account the emergence of these new commodities. Since mineral fuels undergo a special fiscal treatment, incurring excise taxes, the European Commission conceived a particular legal fiscal scheme for the promotion of biofuels.

Accordingly, Member States had been given the possibility to create a detaxation system for biofuels. The Council supported this framework and unanimously approved the Energy Taxation Directive.

In 1998, the European Commission defined specifications for fuels (petrol, diesel, gas-oil) for transport ensuring a high level of human protection and environment preservation[5].

In 2007, the European Commission has initiated the revision of these standards by including also biofuels for better climate change mitigation. As a result of the new changes, fuel suppliers will be bound to reduce their greenhouse gas emissions, including by blending biofuels in the conventional fuels.

In 2008, the European Commission released the major legislative act that is defining the evolution of the European biofuels sector in the next ten years. The main provisions of the Renewable Energy Directive are the following: renewable energy for all sectors and especially for the transport sector will have to follow binding targets for 2020; sustainability criteria are imposed for the first time upon a series of products, namely for biofuels; a certification scheme for sustainable biofuels will be put in place; a promotion scheme for advanced biofuels pathways has been developed.

Binding targets for renewable energy in transport (10% in all Member States) and for renewable energy in final energy consumption (20% in all Member States). The Commission proposal confirmed the conclusion of the March 2007 Energy Council defining a 20% target for all renewable energies an a target of at least 10% for biofuels (meaning that the renewables mix used to attain the overall 20% target shall contain at least 10% of renewable energy in transport in all Member States).

The first directive on biofuels 2003/30/EC

The European Commission intensified its climate change mitigation work in the recent years, while at the same time considering the need for improved security of supply and sustained rural development. Standing in the cross-road of these three challenges, biofuels have been acknowledged for their advantages and accordingly the European Commission build a framework for their promotion. The first move towards an EU biofuels policy was represented by the European Commission Green Paper “Towards a European strategy for the security of energy supply” published in November 2000.

In May 2003 Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport was adopted. Its provisions require Member States to introduce legislation and take the necessary measures to ensure that, as from 2005, biofuels account for a minimum proportion of the fuel sold on their territory.

More specifically, the Directive sets EU reference targets on the basis of which Member States shall set their national indicative targets. In practice, Member States must ensure that the minimum share of biofuels sold on their markets is 2% by 31 December 2005 at the latest, and 5.75% by December 2010. Although the targets were “indicative”, it was anticipated that these objectives would have a strong political value and would influence the choice of EU countries.

Moreover Member State setting lower objectives would have had to justify this to the European Commission on the basis of objective criteria.

Also the "Biofuels" Directive provided that Member States should submit before 1 July each year a report to the Commission, detailing the measures taken to promote the use of biofuels and other renewable fuels, the national resources allotted to the production of biomass for energy purposes other than transport and the total quantities of fuels for transport sold in the course of the year. The purpose of the reporting requirement was for the Commission to first present the progress achieved to the European Parliament and to the Council and secondly, to evaluate the potential for legislative updates.

Biofuels use regulations in Brazil

Biofuels specifications have always been an issue of the petroleum regulatory agencies, CNP[(1)], DNC[(2)] and now ANP[(3)]. Biofuels content in fossil fuels were under CNP and DNC decision up to 1993. In 1998, when the Country was being prepared to open the petroleum market, was created the ANP (Agencia Nacional de Petroleo, Gás Natural e Biocombustíveis). This regulatory agency has more duties then the previous one including regulations on oil and gas production.

In 1980 was agreed between Petrobras and automotive industry, under CNP authority, to increase Brazilian gasoline octane number by adding up to 20% volume of bioethanol to gasoline and starting a lead phase down in the country. Petrobras gasoline became lead free in 1989 without any legislation issued for this. In 1993 was issued a law that mandated that all gasoline sold in Brazil must contain 22% volume of bioethanol.

The reason pointed out by who proposed this law was that since 1986 there was in force in Brazil emissions legislation and all vehicles produced to comply with this legislation were designed to run with a mixture of bioethanol/gasoline (22% bioethanol) and if the amount of bioethanol in gasoline changed these vehicles will not meet the emissions limits.

The law issued in 1993 was modified and today bioethanol content in gasoline is a fixed amount but it can go from 20% to 25% in volume. Bioethanol content in gasoline, is a fixed amount defined by an Agricultural Ministry decree and is dependent of bioethanol production/availability, and must be between 20-25% in volume.

At the beginning of the ethanol programme the Brazilian economy was controlled by the government which set prices and the oil industry was a monopoly. As the economy became more open, ethanol programme experienced a drawback and ethanol shortages emerged. Today the Brazilian economy has been liberated and the government is no longer involved in price setting and it uses taxation to promote the use of biofuels.

Biodiesel Program began in mid of 2003 when a task force was created by the Government to study biodiesel production viability. In 2004 ANP issued regulations regarding biodiesel specification and regulations to organize productive sector. At the end of 2004 Brazilian Government began officially the biodiesel program.

The original schedule established that: in 2005 a 2% biodiesel addition would be optional, in 2008 a 2% biodiesel addition would be mandatory and in 2013 a 5% biodiesel addition would be mandatory too. This original schedule was changed and in July of 2008 a 3% biodiesel addition became mandatory and in July of 2009 a 4% biodiesel addition became mandatory. Biodiesel commercialization is done by auctions coordinated by ANP and Petrobras and REFAP S.A. are the buyers and biodiesel producers are the sellers

Biodiesel programme in Brazil has an important social aspect by promoting family biodiesel feedstock production and giving priority for poorest areas of the country. Government uses taxation as a way to promote the biodiesel programme focusing these two aspects: family feedstock production in some Brazilian areas.

CNP (Conselho Nacional de Petroleo – *National Petroleum Council*)
DNC (Departamento Nacional de Petróleo – *National Petroleum Department*)
ANP (Agencia Nacional de Petróleo, Gás e Biocombustíveis – *National Agency for Petroleum, Gas and Biofuels*)

Government Regulations & Investment in Technology

In general government regulation and investment into biofuels helps develop a biofuels market. The information below is provided on new investment and regulatory action in the United States with regard to biofuels.

American Investment in Biofuels

- 2009 American Recovery & Reinvestment Act
- Dept of Energy receives US$16 billion in a supplemental appropriation
- US$800 million for biomass in applied research, development, demonstration and deployment activities
- US$300 million for the Alternative Fueled Vehicles Pilot Grant Program
- US$400 million for Transportation Electrification
- US$1.52 Billion for a competitive solicitation for a range of industrial carbon capture and energy efficiency improvement projects
- US$6 billion appropriation to support US$60 billion in loan support for smart grid and biofuel facilities.

2010 Budget of the United States

- 2010 budget plans to double investment in basic sciences in energy.
- Loan guarantees and investment into Renewable Energy Projects, Transmission Projects, and Carbon Sequestration Projects that avoid, reduce, or sequester air pollutants and greenhouse gases while simultaneously creating green jobs and contributing to long-term economic growth and international competitiveness.
- Invests in Clean Energy Technologies to reduce dependence on foreign oil and accelerate the transition to a low-carbon economy.

American Subsidies and Tariffs

Subsidies

- Blenders' Credit – US$.45 per gallon – Expires 31 December 2010.

- Biodiesel Income Tax Credit - US$1.00 per gallon – Expires 31 December 09.

- Small Ethanol Producer Credit - US$1.5 million ann. – Expires 31 Dec 2010.

- E85 Infrastructure Credit – Max US$30k annually – Expires 1 January 2010.

- Infrastructure Dev. Grants - US$200 million ann. - 2010 budget?

- Depreciation Allowance for Cellulosic Biomass Ethanol Plant – 50% in first year. Accelerated depreciation becomes tax incentive - Expires 31 December 2012.

Tariffs

- Ad Valorem Import Tariff - approximately US$.036 per gallon.

- Secondary Tariff - US$.54 per gallon used to offset Blenders' Credit for non-U.S. and non-Caribbean countries. (note: Ethanol imports from countries that are part of the North Atlantic Free Trade Agreement, Caribbean Basin Initiative, and Andean Trade Preference Act may not be subject to the secondary duty provided the ethanol is fully produced with feedstocks from those nations).

In 2006 as crude oil prices were rising, the President of the United States of America in his "State-of-The Union" address pledged increased support for ethanol production across the country, both from maize and in the future from the extensive lignocellulosic resources such as agricultural straws and wood. The US Congress approved a very ambitious Renewable Portfolio Standards (RPS).

The potential of biofuels for transportation is however quite finite; current global food production corresponds to a primary energy content of about 30 EJ/yr, while crude oil alone is around 160 EJ/yr. Thus the projected large growth of ethanol from maize in the USA could use up to 40% of today's crop (up from around 16%). The USA is the swing producer of maize, contributing about 40% to internationally-traded corn

In terms of the environmental impact, the production of ethanol from corn is only marginally energy-positive at about 1.4:1, but sugarcane in Brazil has a ratio of about 8 units of renewable liquid fuel to one of fossil energy input. Brazil has phased out most agricultural subsidies to its sugar industry, but the agricultural sectors of the USA and the EU still receive large subsidies for agricultural products, including ethanol and other biofuels.

The US spends about US$5billion per year at present. Agricultural subsidies have been challenged during the Doha round of World Trade Organization negotiations as being bad for the environment (by encouraging intensive agriculture) and for their negative effects on the development of agriculture in third-world countries.

Many of these countries would be capable of becoming major players (using Brazilian biofuels as an example) if there were neither subsidies nor tariff barriers such as the US$ 143/m3 (54 c/US gal) imposed by the USA on Brazil.

Biodiesel

The second-generation biodiesel is often called 'renewable diesel' and is produced by treating vegetable oil with hydrogen over catalysts in oil refineries, to either blend or be co-processed with 'fossil diesel'. The resultant product can be used in the range of B5 – B50. As a fuel, the FAME biodiesel has about 90–95% of the volumetric energy content of regular diesel, and in combustion reduces some of the particulate and carbon monoxide emissions.

The effect on NOx is not so clear cut, with many studies showing a slight increase.

In addition to vegetable oils, animal fats such as tallow and waste grease can also be converted to FAME; they are the lowest-cost resources available, mainly in urban areas.

The commercial resource base for vegetable oils comprises about 20 different species with soybean oil, palm/palm kernel oil, sunflower, rapeseed (Colza), and coconut oils being the largest sources.

Despite the current minority position of biodiesel relative to ethanol, the adoption of mandates in several countries will fuel a large growth in the near future. Brazil, for example, has a nationwide mandate for B2 in 2008 resulting in an estimated 1.1 hm3 demand for biodiesel (935 kt).

The EU mandates for 5.75% biofuels in the transportation sector by 2010 are driving the rapid growth of biodiesel in the major EU economies and, like ethanol, production has leapt in the last few years

The estimated output for 2006 at 7.5 mt is equivalent to 6.8 mtoe or 0.3 EJ energy equivalent. While the energy balance for rapeseed biodiesel is around 4 units of energy for each unit of fossil input, it can be as high as 8:1 for high-yielding palm oil biodiesel.

The processing of both rapeseed and soy produces considerable quantities of co-product meal which is used as an animal feed. The growing fuel market is introducing distortions into the animal-feed supply system, which is also having to accommodate increasing amounts of dried distillers' grains and solubles (DDGS) from the corn-ethanol production system. The two largest producers of palm oil are Malaysia and Indonesia and in 2006, the two countries agreed to limit the development of further facilities to 6 mt of palm oil capacity to be able to evaluate the expansion.

6. Sustainability Criteria

Sustainability of Bioenergy

The primary goal of developing the biofuels sector is sustainability. The sustainability driver is based on the three pillars of economic, social and environmental sustainability.

Subsidies for production of biofuels feedstock can distort markets. They may contribute to inefficient allocation of resources, and thus also have a negative impact on food markets.

> Defining the sustainability criteria for biofuels is a complex task which may have crucial implications for market development. Broad stakeholder involvement and comprehensive consultation are necessary for a balanced and feasible outcome of the process.

This is not an attempt to create a sustainability standard per se. On the contrary, it is an attempt to create a framework presenting the main principles and criteria, based on existing standards.

Finally, it is necessary to look into the greenhouse gas emissions savings and accounting principle. This principle is drafted in accordance with key policy indications facilitating the inclusion of legislative provisions in future sustainability meta-standards.

Sustainability principles and criteria

The sustainability principles are the overarching goals which form the actual sustainability framework. One level below in the sustainability structure, there is criteria for each principle. The criteria specifies the concrete aspects of each principle. (See ANNEX 8 for more detail)

However, there are individual indicators which enable verification and auditing.

Sustainability is regarded as a threefold paradigm, entailing social, economical and environmental dimensions. Defining the sustainability criteria for biomass for energy applications is a complex process which has crucial market implications.

In the end, if not designed correctly, sustainability and certification schemes will undoubtedly trigger significant market disruptions. This is finally what all stakeholders are committed to avoid in any environmental-related field that is ruled by the "precautionary principle".

A sustainability standard should account for all three fields, while adding specifications on the greenhouse gas emissions savings, lifecycle assessment, chain-of-custody, verification and auditing.

Energy sustainability

Energy sustainability means the provision of energy in such a way that it meets the needs of the present without compromising the ability of future generations to meet their needs. Sustainable energy sources are most often considered to be renewable energy sources, including biofuels, and also energy efficiency and conservation.

Social sustainability

Social sustainability reflects how the production and use of biofuels, including transport applications, impacts local development. In particular, social sustainability aims to ensure that the human rights, land rights and land use rights are respected. It also addresses issues like labour standards, safety standards and especially agriculture and local development,

Economic sustainability

The economic sustainability is a prerequisite for sustainable production of biofuels for energy applications including transportation. Economics is about the efficient use of resources, usually expressed in monetary terms.

The concept of economic sustainability is subject, on all levels, to different inputs and outputs. The economic sustainability of a nation is subject to the whole economy on local, national and international level.

Environmental sustainability

Environmental sustainability addresses issues related, but not restricted to biodiversity, land preservation, water and soil preservation.

Greenhouse gas emissions reductions

The GHG aspects have been triggering important debates and controversies. We limit ourselves to underlining the main discussion points that are consistently at the core of the sustainability standardization process.

The Life Cycle Assessment (LCA) of the production of biofuels for energy applications or other end uses represents the tool most widely used for the GHG balance accounting.

Principles for an objective LCA of biofuels

A considerable number of LCA studies have been conducted for the assessment of biofuels production in Europe and other parts of the world. The purpose is to investigate and evaluate the environmental impacts of biofuels production (as far as GHGs and energy balances are concerned) and the ranking of best performing pathways. (See ANNEX 9 for more detail)

However in the same biofuels production pathway, LCA studies produce very different results. That is why it is essential to carefully design a reference study, especially when it constitutes scientific underpinning of legislative measures which have far-reaching implications for the industry.

> Considering all LCA studies conducted so far, a transparent and objective study to evaluate the performance of biofuels worldwide becomes essential to accurately reflect the genuine performances of biofuels.

One example of biofuels LCA study was performed by the Commission Joint Research Centre, in collaboration with EUCAR and CONCAWE1 (referred herein as the JEC study), which was integrated in the recently adopted EU Renewable Energy Directive.

The JEC study has therefore been elaborated by experts from the mineral oil and automotive industries, without input from the agricultural and bioenergy sectors. As a result, the scientific foundation of the new Renewable Energy Directive is still questioned by stakeholders for a lack of balanced contributions from all parties and in all areas of expertise.

In light of the above example, an objective reference LCA study detailing the performances of biofuels is needed in a twofold perspective: The Renewable Energy Directive, an essential piece of European legislation, should be based on a study that was commonly accepted by all stakeholders as being objective, balanced, transparent and reflecting reality.

The JEC study needs therefore to be turned into an EU scientific reference for biofuels LCA, including the expertise from farmers and bioenergy producers.

Given the growing importance international trade flows of biofuels and bioenergy, there is an increasing need to create an internationally acceptable unified system measuring the sustainability and the GHG performance of biofuels.

Against the background of a lack of consistent data and methodologies used world-wide and the availability of a multitude of balanced, yet not fully updated Biofuels Life Cycle Assessments, it appears particularly crucial to start working **towards an up-to-date objective and transparent Biofuels Life Cycle Analysis Study established at international level**.

A common and transparent approach, including all interested stakeholders at international level, is necessary in order to draw any meaningful conclusion from the comparison of different biofuels chains with corresponding fossil fuels. Objective figures and methodologies must be elaborated to enable international measurement of biofuels sustainability.

Biodiesel Life Cycle Assessment (LCA) Studies provide an opportunity to quantify the total greenhouse gas emissions and savings for different biodiesel pathways. Also they quantify energy demands and overall energy efficiencies for processes and/or final products. Life Cycle Assessment studies so far presented the results in a comparative way: biodiesel/bioethanol pathways versus the regular diesel which finally enables all readers to correctly estimate the biofuels potential to greening the transport sector worldwide.

Understanding the overall energy requirements of biodiesel is key to describe biodiesel made from vegetable or animal, new or used oil, as a “renewable energy” source. In general, the more fossil energy required producing a fuel, less we can say that this fuel is “renewable”. Thus, the renewable nature of a fuel can vary across the spectrum from “completely renewable” (i.e., no fossil energy input) to non-renewable (i.e., fossil energy inputs as much or more than the energy output of the fuel).

This section focuses on the review of the life cycle assessment and the energy efficiency assessment of biodiesel. The approach embraced is to compare for every indicator (e.g. fossil fuel ratio) biodiesel with the petroleum diesel specified by the European Standard EN 590.

The most relevant indicators reviewed for biodiesel and diesel EN 590 are: life cycle energy demand and inventory, fossil fuel inventory, fossil fuel ratio, energy efficiency of the production and the distribution of both fuels. Next, a sensitivity analysis has been conducted in order to understand the changes in indicators’ values in different alternative scenarios. Lastly, the technical aspects of end-use technologies are explained.

Fossil Energy Ratio =
Fuel Energy/Fossil Energy Inputs

If the fossil energy ratio is equal to 1, then the fuel is non-renewable. A fossil energy ratio of “one” means that no loss of energy occurs in the process of converting the fossil energy to a useable fuel. For fossil energy ratios greater than 1, the bigger the ratio, the more “renewable” becomes the fuel. As a fuel approaches being “completely” renewable, its fossil energy ratio approaches “infinity.” In other words, a completely renewable fuel has no fossil energy inputs.

From a policy perspective, these considerations are valuable. Policymakers want to understand the extent to which a fuel increases the “renewability” of our energy supply. Another implication of the fossil energy ratio is the question of climate change. Higher fossil energy ratios (that means that the fuels are more from renewable sources) imply lower net CO2 emissions. This is a secondary aspect of the ratio, as we are explicitly estimating total CO2 emissions from each fuel’s life cycle. Nevertheless, the fossil energy ratio serves also as a verification tool for the calculations of the CO2 life cycle emissions (since the two indicators should be correlated).

Petroleum Diesel Life Cycle Energy Demand

In order to point out the biodiesel versus petroleum diesel energy efficiency and fossil fuel ratio, several LCA studies done by research institutes, consultancies, regional or national administration across the EU have been examined.

For this section the CIEMAT study performed for the Spanish Environment Ministry was reviewed. Its LCA model shows that 1.2007 MJ of primary energy is used to make 1 MJ of petroleum diesel fuel. This corresponds to a life cycle energy efficiency of 83.28%. Ninety-three percent of the primary energy demand is for extracting crude oil from the ground. About 88% of the energy shown for crude oil extraction is associated with the energy value of the crude oil itself. The crude oil refinery step for making diesel fuel dominates the remaining 7% of the primary energy use.

Removing the feedstock energy of the crude itself from the total primary energy allows us to analyze the relative contributions of the process energy used in each life cycle. Process energy demand represents 20% of the energy. Using the total primary energy reported in the CIEMAT Study,

Life Cycle Energy Efficiency =
1 MJ of Fuel Product Energy/1.2007 MJ of Primary Energy Input = 0.8328

Life Cycle Inventory of Biodiesel and Petroleum Diesel ultimately available in the petroleum diesel fuel product. About 90% of the total process energy is in refining (60%) and extraction (29%). The next largest contribution to total process energy is for transporting foreign crude oil to domestic petroleum refiners.

Biodiesel Life Cycle Energy Demand

Compared on the basis of primary energy inputs, biodiesel and petroleum diesel are essentially equivalent. Biodiesel has a life cycle energy efficiency of 80.55%, compared to 83.28% for petroleum diesel. The slightly lower efficiency reflects a slightly higher demand for process energy across the life of cycle for biodiesel.

One MJ of biodiesel requires an input of 1.2414 MJ of primary energy, resulting in a life cycle energy efficiency of 80.55%. Biodiesel is comparable to petroleum diesel in the conversion of primary energy to fuel product energy (80.55% versus 83.28%). The largest contribution to primary energy (87%) is the vegetable oil[4] conversion step because this is where we have chosen to include the feedstock energy associated with the soybean oil itself.

Fossil Energy Ratio =
1 MJ Fuel Energy/1.1995 MJ of Fossil Energy Input = 0.8337

Life Cycle Energy Inventory of Biodiesel and Petroleum Diesel

[4] Energy contained in the soybean oil itself represents, in effect, the one place in the biodiesel life cycle where input of solar energy is accounted for. Total radiant energy available to soybean crops is essentially viewed as "free" in the life cycle calculations. It becomes an element accountable in the life cycle only after it has been incorporated in the soybean oil itself.

This is analogous to counting the feedstock energy of crude petroleum as the point in its life cycle where solar energy input occurs. Petroleum is essentially stored solar energy. The difference between petroleum and soybean oil as sinks for solar energy is their time scale. While soybean oil traps solar energy on a rapid ("real time") basis, petroleum storage represents a process that occurs on a geologic time scale. This difference in the dynamic nature of solar energy utilization is the key to the definitions of renewable and non-renewable energy.

For Diesel 590 the production stage which is most energy consuming is extraction, followed by refining and distribution of fuel to the filling stations.

For the biodiesel production from new vegetable oils, the most energy intensive stage in the production is cultivation. The trans-etherification stage (where the oil and the methanol are mixed for obtaining biodiesel) actually saves energy from a system expansion perspective.

From all the pathways in this category, soy oil is consuming both most primary energy (44,64 MJ/kg) and most fossil energy (25,63 MJ/kg), while sunflower oil requires the smallest amount both for the total primary (23,58 MJ/kg) and for fossil energy (14,34 MJ/kg). Also rapeseed oil is efficient, requiring only 26,86 MJ/kg primary energy and 15,58 MJ/kg fossil energy.

When biodiesel is produced from used oils, the energy (total primary and fossil) consumption is incontestably reduced compared to diesel or biodiesel from new vegetable oils. Moreover, it is considered that the collection of used oils is energy neutral despite existing stringent laws requiring special collecting and disposal of all used oils as waste.

Fossil fuel inventory and fossil energy ratio of biodiesel and petroleum diesel

Biodiesel has a positive fossil energy ratio because most of its feedstock requirements (on average 90 %) are renewable (i.e. the oil is of vegetal nature). On the basis of fossil energy inputs, biodiesel enhances the effective use of this finite energy resource. Fossil energy demand for the conversion step is almost twice that of its process energy demand, making this stage of the life cycle the largest contributor to fossil energy demand, after the cultivation step.

Another assumption in the literature is to have natural gas derived methanol for the conversion step. This reveals an opportunity for further improvement of the fossil energy ratio by substituting natural gas-derived methanol with renewable sources of methanol, ethanol or other alcohols.

The basic hypothesis for calculation of the fossil fuel inventory is that the biodiesel is produced from different origins and the fossil fuel is accounted for in all stages apart from the distribution one.

The results of the CIEMAT 2006 study show that there is a **4 to 1 ratio** of final fuel to fossil fuel for the **biodiesel from crude vegetable oils** and a **44.4 to 1 ratio for the biodiesel from used oils**. The fossil energy ratio for diesel EN-590 is 1 which means that for 1 MJ of final energy 1 MJ of fossil energy is required.

Other studies carried by research institutes or universities show similar results for the fossil energy ratio calculated on the same basis (MJ final fuel/MJ fossil energy):

- ADEME, 2002: Rapeseed: 3,03 and unflower: 3,16
- - IFEU, 2000: Rapeseed: 5,46 and Sunflower: 5,83[7]
- - Wiewls, 2004: Rapeseed: 5,24
- - Rollefson et al, 2002: Rapeseed:2,06
- - Ecobilan 2002: Rapeseed: 2,99 and Sunflower: 3,16
- - USDA, 1998: Biodiesel uses 0.3110 MJ of fossil energy to produce one MJ of fuel product; this equates to a fossil energy ratio of 3.215. In other words, the biodiesel life cycle produces more then three times as much energy in its final fuel product as it uses in fossil energy.

Energy Efficiency of the production and distribution of diesel EN-590 and biodiesel from crude and used vegetable oils

The final energy (primary and/or fossil) is greater than the total input energy used to produce the final fuel. The exceptions are the Diesel EN-590 and the B5 (diesel EN-590 blended with 5% Biodiesel) from both crude and used vegetable oil.

Logically, the more biodiesel is blended, the higher are both the energy efficiency and the fossil fuel ratio.

Sensitivity analysis

The purpose of conducting a sensitivity analysis is to clarify the relevance of the variables used in the main analysis. The way to perform the sensitivity analysis is to elaborate alternative scenarios and to test alternative hypothesis.

Accordingly the results will confirm or infirm the variables and the main results.

As it was expected, when using the economic value method of allocation for the by-products, the energy used in the process increased considerably, but especially in the one-oil biodiesel fuels (not the oil mixes). Accordingly the energy efficiency and the fossil energy ratios are worsening.

End-Use Technologies

Some consideration is necessary on the end-use technologies of the fuels modelled in the large majority of studies. This assessment is using some basic assumptions of the end-uses to consider, such as:

- Use of biodiesel and low-sulphur diesel fuel in modern urban diesel buses
- Fleet use only (a consequence of the previous assumption)
- Engine-specific comparisons

For the relevance of any end-use technologies analysis, it is important to limit the end-uses of the fuels to a single application. Bus applications examples have been chosen due to the wide availability of information.

Moreover, introducing this limitation to bus applications, allows the use of the best available empirical database on biodiesel. Urban buses applications are called “fleets” and they have a central fuelling system.

The other important aspect of end-use technologies is the engine-specific comparisons between the two fuel alternatives (biodiesel and petroleum diesel). By analysing any database (e.g. the biodiesel database used by the USDA Study 12), a simple conclusion can be extrapolated: emissions will vary considerably according to the type of fuel used, to the engine, etc.

Against this background, as a technical aspect of conducting end-use technologies analysis, it is absolutely necessary to choose a particular type of engine and to compare the use of different types of fuels in that engine, or to chose a particular fuel blend and to compare its performance using different engines.

This study analysed in a comparative approach the energy efficiency and the fossil fuel ratio of biodiesel and of diesel EN 590. It was conducted by surveying the relevant literature and concluded that the energy efficiency of biodiesel is almost the same as the energy efficiency of the diesel EN 590.

However the crucial difference between the two fuels is in the fossil fuel ratio, the studies cited showing a fossil fuel ratio very positive for biodiesel (in a range of 2.06 – 5.46 MJ of final primary energy/MJ fossil energy). Consequently, these results show that biodiesel is once again demonstrating its unquestionable renewable nature and benefits.

That study analysed in a comparative approach the energy efficiency and the fossil fuel ratio of biodiesel and of diesel EN 590. The study concluded that the energy efficiency of biodiesel is almost the same as that of diesel EN 590. However the crucial difference between the two fuels lies in the Fossil Fuel Ratio which was considerably more positive for biodiesel (in a range of 2.06 – 5.46 MJ of final primary energy/MJ fossil energy). These results confirm the renewable nature and benefits of biodiesel.

Environmental Issues Generally Associated with Biofuels

Biofuels and other forms of renewable energy are used to control and decrease emissions associated with production and use of various fuels. Carbon neutral means that the carbon released during the production and use of biofuels is re-absorbed by the plants. Adequate policies and economic instruments should help ensure that biofuels commercialisation, including the development of new cellulosic technologies, is sustainable.

When land is cleared, vegetable matter that absorbs GHG is removed, and therefore CO_2 emitted by the vehicles used for clearing land adds to higher emissions.

The most common issues include:

- Agricultural residues left after seeds removal (e.g. cobs, pods, stems etc) add to the environmental problems.
- Combustion of biodiesel and bioethanol produces CO_2 and some other gases.
- The presence of oxygen in biodiesel improves combustion and therefore reduces hydrocarbon, carbon monoxide and particulate emissions but oxygenated fuel tends to increase nitrogen oxide emissions.
- During fermentation of bioethanol, carbon dioxide is released, and large quantity of water used for hydrolyses and fermenting.
- Distillation produces heat, i.e. thermal pollution.

Environmental impacts also include the following:

- Agrochemicals used in the farming of energy crops.
- Emissions from growing the feedstock (e.g. petrochemicals used in fertilizers and transport of water).
- Emissions from transporting the feedstock and water to the processing plant.
- Emissions from processing the feedstock.
- Emissions from the change in land use of the area where the fuel feedstock is grown.
- Emissions from transportation of the biofuels from the processing plant to the point of use.
- Carbon dioxide produced at the tail pipe.
- Emissions generated by controlled burning of the plantation for harvesting, instead of using mechanical harvesting.

While it is recognised that biofuels have the capacity to reduce greenhouse gas emissions compared to fossil fuels, their production and use are not entirely without environmental implications. Depending on the crop type, carbon balance is not always smaller than for fossil fuels.

Standardisation of sustainably grown biomass for biofuels

Since the production of biofuels in general is closely related to agricultural activities, the production in Europe follows the EU Common Agricultural Policy rules that lay down all environmental standards for agricultural production.

Therefore the sustainability of European biodiesel and bioethanol is guaranteed by the Cross-compliance rules followed by the European Farmers and by all social and economical standards of developed economies.

As a result the European production of biofuels does not contribute to deforestation or land degradation due to existing management practices and stringent environmental legislation in the European Member States.

Sustainable biofuel production practices would not hamper food and fibre production nor cause water or environmental problems but would actually enhance soil fertility.

7. Conclusions and Recommendations

The world´s transport system is based on one single fuel - oil and today there does not seem to be any realistic alternative to oil. Demand for oil is expected to grow for decades to come, along with the overall demand for energy. Biofuels can help meet this demand, and even if they will not replace oil, they should be regarded as an integral part of the energy mix.

To achieve a rapid increase in biofuels production that can be sustained over the long term, policies that are consistent, long-term and supported by broad stakeholder participation are needed. They should also be a part of larger transportation goals. Increasing efficiency still remains the cheapest way to alleviate the pollution and security risks associated with petroleum use.

Supportive government policies have been essential to the development of modern biofuels over the past two decades. Blending regulations, tax incentives, government purchasing policies and other measures have been used to support biofuels. Development of infrastructure and technologies have been most successful in increasing biofuels production. Countries planning to develop domestic biofuel industries will be able to draw important lessons—both positive and negative—from the industry leaders, in particular Brazil, the United States, and the European Union.

Introducing new energy crops will require particular attention from governments in designing their national agricultural policies that have a significant impact on the choice of which crops to grow. It is also essential that governments promote biofuels within the context of a broader transition to a more-efficient, less polluting, and more diversified global transport sector.

Biofuel policies should focus on market development and facilitate sustainable international biofuel trade. The geographical disparity between production and demand for biofuels will require the reduction in barriers to biofuel trade. Free movement of biofuels around the world should be coupled with social and environmental standards and a credible system to certify compliance.

Tax incentives have been used successfully in Brazil, Germany, the United States and other countries to spur biofuel production and reduce biofuel prices at the pump. The enormous purchasing power of governments has been used successfully in a number of countries to expand the market for various products.

Use of vehicles and fuels that are certified under sustainability schemes by governments could provide a powerful market driver. Local governments can switch entire fleets to run on biofuels. National governments could gradually increase the share of vehicles fueled by biofuels up to 100 percent; except for military vehicles.

Consumer demand could be another powerful driver of the renewable fuels market. Strategies to increase public awareness about biofuels include various forms of public education, such as formal awareness campaigns, public announcements, university research, etc.

Low-interest, long-term loans and risk guarantees are required to facilitate the development of commercial refineries and “biorefineries.

"Safety and certainty in oil lie in variety and variety alone"

Winston Churchil

If biofuels continue their rapid growth around the globe, the impact on the agricultural sector will be significant. More jobs and stronger economic development in rural areas in both industrialized and developing countries is a distinct possibility. The more involved farmers are in the production, processing, and use of biofuels, the more likely they are to benefit from them.

In regions where access to modern forms of energy is limited or non-existent, governments and development agency support for small-scale biofuel production can help provide clean, accessible energy that is vital for rural development and poverty alleviation.

Also as renewable fuel use becomes more widespread, opportunities for countries with more developed biofuels industries to export their technologies will expand.

Since biofuels may be categorised as agricultural goods under the WTO Agreement on Agriculture, industry may seek an exemption from the Agreement's restrictions on domestic price supports.

Alternatively, if biofuels are categorized as industrial goods, they may qualify for treatment as "environmental goods." To be included in such a category they should be required to meet strict environmental standards for their production.

Governments should promote biofuels within the context of a broader transformation of the transportation sector, since biofuels alone will not solve the world's transportation-related energy problems.

To achieve their full potential to provide supply security, environmental, and social benefits, biofuels need to represent an increasing share of total transport fuel relative to oil.

1. Governments should pursue efforts that lead to diversification of transport fuel sources to improve economic, energy and environmental security.

2. Agricultural policies should balance the need for food and water supplies with biofuels production.

3. When performing analysis of fuel source and type, a cradle-to-grave LCA is necessary for understanding of economic, energy and environmental impacts using a common, objective and transparent methodology.

4. Governments should conduct research to gain a better understanding of impacts of biofuels production and use on public health and local environment, as for other energy sources.

5. Governments and industry should invest in biofuels research and development to stimulate breakthrough technologies and share best practices and technologies for biofuels production and use.

6. Governments should pursue policies to encourage private sector investment into commercial scale production of biofuels – for proven technologies, including incentives for scaling-up technology from pilot to demonstration to commercial scale.

7. Each country should strive to develop open and free markets for biofuels, although “grandfathering” subsidies, tariffs and other tools might be needed until domestic markets have been established.

8. All agricultural policies and strategies are based on local, national or in some cases regional circumstances and they include the mix of environmental (land, water, climate), social (population, education) and economic (infrastructure, governance) factors. It is therefore impossible to develop “one-size-fits-all” policies for biofuels.

9. Identifying the right place of biofuels production in the agricultural economy, including choices of the actual types (diesel from vegetable oil, ethanol from sugar or starch crops, solid biofuels from wood or grass sources) is a significant policy challenge.

10. While it is recognized that biofuels have the capacity to reduce greenhouse gas emissions compared to fossil fuels, their production and use are not entirely without environmental implications. Depending on the crop type and other factors, carbon emissions are not always lower than for traditional fuels.

Abbreviations and Acronyms

10^3	kilo (k)
10^6	mega (M)
10^9	giga (G)
10^{12}	tera (T)
10^{15}	peta (P)
10^{18}	exa (E)
10^{21}	zetta (Z)
AC	alternating current
API	American Petroleum Institute
b/d	barrels per day
bbl	barrel
bcf	billion cubic feet
bcm	billion cubic metres
billion	10^9
boe	barrel of oil equivalent
C	Celsius
cf	cubic feet
cm	centimetre
CNG	compressed natural gas
CO_{2e}	carbon dioxide equivalent
DC	direct current
FAO	UN Food and Agriculture Organization
ft	feet
g	gram
GEF	Global Environment Facility
GHG	greenhouse gas
h	hour
ha	hectare
IEA	International Energy Agency
J	joule
kcal	kilocalorie
kg	kilogram
km^2	square kilometre
LNG	liquefied natural gas
LPG	liquefied petroleum gas
m	metre
m/s	metres per second
m^2	square metre
m^3	cubic metre
mm	millimetre
mt	million tonnes
mtoe	million tonnes of oil equivalent
NGO	non governmental organisation
Nm^3	normal cubic metre
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of the Petroleum Exporting Countries
R&D	research and development
RD&D	research, development and demonstration
R/P	reserves/production
t	tonne (metric ton)
tC	tonnes carbon
tce	tonne of coal equivalent
toe	tonne of oil equivalent
tpa	tonnes per annum
trillion	10^{12}
UN	United Nations
UNDP	United Nations Development Programme
WEC	World Energy Council
WTO	World Trade Organization

Conversion Factors and Energy Equivalents

Basic Energy Units

1 joule (J) = 0.2388 cal

1 calorie (cal) = 4.1868 J

(1 British thermal unit [Btu] = 1.055 kJ = 0.252 kcal)

WEC Standard Energy Units

1 tonne of oil equivalent (toe) = 42 GJ (net calorific value) = 10 034 Mcal

1 tonne of coal equivalent (tce) = 29.3 GJ (net calorific value) = 7 000 Mcal

Note: the tonne of oil equivalent currently employed by the International Energy Agency and the United Nations Statistics Division is defined as 10^7 kilocalories, net calorific value (equivalent to 41.868 GJ).

Volumetric Equivalents

1 barrel = 42 US gallons = approx. 159 litres
1 cubic metre = 35.315 cubic feet = 6.2898 barrels

Electricity

1 kWh of electricity output = 3.6 MJ = approx. 860 kcal

Representative Average Conversion Factors

1 tonne of crude oil = approx. 7.3 barrels

1 tonne of natural gas liquids = 45 GJ (net calorific value)

1 000 standard cubic metres of natural gas = 36 GJ (net calorific value)

1 tonne of uranium (light-water reactors, open cycle) = 10 000–16 000 toe

1 tonne of peat = 0.2275 toe

1 tonne of fuel wood = 0.3215 toe

1 kWh (primary energy equivalent) = 9.36 MJ = approx. 2 236 Mcal

List of Annexes

ANNEX No.	Title	Author	Organisation
ANNEX 1	Country Case Studies		
ANNEX 2	Automotive Fuel Quality Regulations and Strategies in Japan	Kenichiro Saitoh	Nippon Oil Corporation
ANNEX 3	Various Biofuels Feedstocks and the Associated Issues	Prof. Bamidele Ogbe Solomon	National Biotechnology Development
ANNEX 4	Biofuel Applications in Internal Combustion Engines	Dr Ian J. Potter	Alberta Research Council
ANNEX 5	Challenges and Opportunities Productivity Improvement in Agriculture	Prof. Bamidele Ogbe Solomon	National Biotechnology Development
ANNEX 6	Classification, Certification and Standardization Including Lifecycle Assessments of Biofuels	Raffaello GAROFALO	EBB - European Biodiesel Board
ANNEX 7	The EU Biofuels Policy and Regulatory Landscape	Raffaello GAROFALO	EBB - European Biodiesel Board
ANNEX 8	Sustainability Criteria for Biomass and Biofuels	Raffaello GAROFALO	EBB - European Biodiesel Board
ANNEX 9	LCA Studies for the Harmonisation of International Biofuels Sustainability Assessment	Raffaello GAROFALO	EBB - European Biodiesel Board
ANNEX 10	Energy Efficiency and End-Use Technologies of Biodiesel Production	Raffaello GAROFALO	EBB - European Biodiesel Board

Bibliography

Alakangas, Eija. Valtanen, et al. (2006). "CEN technical specification for solid biofuels-Fuel specification and classes." Biomass & Bioenergy 30: 908-914.

The European Committee for Standardization, CEN (TC335) is currently preparing 30 technical specifications for solid biofuels. The two most important technical specifications being developed deal with classification and specification (CEN/TS 14961) and quality assurance for solid biofuels (CEN/TS 15234). The classification of solid biofuels is based on their origin and source. The fuel production chain of fuels shall be unambiguously traceable back over the whole chain. The biofuels are divided into the following sub-categories for classification: (1) woody biomass, (2) herbaceous biomass, (3) fruit biomass and (4) blends and mixtures. The purpose of classification is to allow the possibility to differentiate and specify biofuel material based on origin with as much detail as needed. The quality classification in a table form was prepared only for major traded solid biofuels: briquettes, pellets, exhausted olive cake, wood chips, hog fuel, wood logs, sawdust, bark, and straw bales. Additionally, a general table was compiled for other biofuels. The most significant properties are normative, and shall be stated in the fuel specification. The classification is flexible, and hence the producer or the consumer may select from each property class the classification that corresponds to the produced or desired fuel quality. This so called "free classification" does not bind different characteristics with each other. An advantage of this classification is that the producer and the consumer may agree upon characteristics case-by-case. To protect household consumers, examples of so-called "high-quality" fuels are given as an informative annex A of CEN/TS 14961. This paper describes the fuel specifications and classes of solid biofuels, which was published in April 2005

Alakangas, Eija. Vesterinen, et al. (2006). "Efficient trading of biomass fuels and analysis of fuel supply chains and business models for market actors by networking."
China. European bioenergy network, EUBIONET 2 was established in 2005 and it concentrates on biofuel markets and fuel supply chains in Europe. The EUBIONET 2 is a two year project funded by EU in the framework of Intelligent Energy - Europe Programme. The project aims to give a clear outlook of the current and future biomass fuel market trends in Europe; provide feedback on the suitability of CEN 335 biofuel standards for trading of biofuels; give well-analysed estimation on techno-economic potential of the biomass fuel volumes to the year 2010 based on the existing studies and experts' opinions; enhance biomass fuel trade and technology transfer by networking of different actors; analyse, select and describe the most suitable trading and business models for small and large scale biofuel supply chains for heat and power production by taking into account the environmental aspects and sustainability; enhance biomass use by cooperation and information dissemination with different market actors in the fuelutilisation chain.

Alakangas, E., T. Lensu, et al. "Review of the present status and future prospects of standards and regulations in the bioenergy

field." Alakangas, E., M. Sc, et al. "The European pellet standardisation."
The European Committee for Standardization, CEN, is currently preparing about 30 technical specifications for solid biofuels (TC335). The aim is to promote the trade of biofuels, so that the customer and the seller can unanimously define the quality of solid biofuels. Finland is leading the preparation of technical specifications; Fuel specification and classes and Quality assurance under Working group 2 (WG). Preparation fo testing methods for pellet durability and other physical properties is carried out by WG4 lead by Sweden. WG3 prepares standards for sampling and sample reduction and WG5 analysis of chemical properties both chaired by the Netherlands. WG1, terminology and definitions, chaired by Germany, has already finalised their work. This paper handles classification and specification of wood pellets and testing of pellet durability.

Anonymous (2000). "Energy Forum. New technical committee, "Solid Biofuels", founded. Standards for biogenic solid fuels." Brennstoff, Warme, Kraft 52: 7-8.

Biogenic solid fuels are natural products and as such have variable properties. Up to now there have been no quality standards for them relating to their use as energy. Facility operators were hard put to procure the proper fuel. To solve this problem, for the first time for all of Europe binding quality and test standards for biofuels are being developed. Despite efforts by governments biogenic solid fuels up to now have been only slightly used to cover energy demands in Germany. This is due to a considerable information deficit, to high costs compared with fossil fuels, and to the lack of binding quality criteria for the production and provisioning and energetic use of biogenic solid fuels. Because of this, the EU Commission has authorized the European Committee for Standards (CEN) to become active in the field of standards for biogenic solid fuels. In the last 18 months with inclusion of all the EU member states and with financial support of the EU Commission a program has been worked out with respect to developing test and quality standards for biomass. This activity is assembled within the technical committee "Solid Biofuels" (CEN/TC 335). The committee is divided into working groups WG 1 "Terminology, Definition, and Description" (one standard); WG II "Fuel Specifications, - Classes, and -Quality Assurance" (two standards); WG III "Taking Samples and Sample Reduction" (two standards); WC IV "Physical-Mechanical Tests" (ten standards); and WG V "Chemical Tests" (nine standards. The activities of the CEN/TC 335 are supported in the CEN member states by so-called panel committees (Spiegel-Komitees). Since 1998 scientists are working under coordination of the University of Stuttgart on the platform for a standardization of biogenic solid fuels. Supported by the Agency of Renewable Raw Materials, it performs advance work for CEN. It wants to work out for the first time binding quality standards for biofuels.

Anonymous (2004). "New York State sets 25 percent renewable energy goal." Biocycle 45: 60. Anonymous (2007). "Industrial biotechnology policy agenda for Europe." Industrial Biotechnology 3: 36-47
Industrial biotechnology (or, as known in Europe, white biotechnology) has thepotential to form the basis of a future EU Knowledge-Based BioEconomy (KBBE) and make European

society both more sustainable and more competitive. But to realize this potential, a number of policy steps must be taken. This report puts forward concrete policy proposals for the EU to encourage the development of a KBBE. Of primary importance is the need to develop policy coherently across the EU and to coordinate its implementation. There are many policy strands and activities which relate to biotechnology (e.g., biofuels, research and innovation, climate change, sustainable development, Common Agricultural Policy left bracket CAP right bracket reform, Environmental Technologies Action Plan left bracket ETAP right bracket); these must be harmonized for consistency and efficiency. Appointment of a KBBE coordinator by the Commission to bring together activities in the various Directorates General (DGs) is essential. At the same time, a KBBE task force is needed to coordinate EU member state programs. It is equally important that the policy be based on sound evidence. Data gathering, collation, and analysis underpin the whole process: Good policy cannot be formulated without good data. At the other end of the policy-making process, a comprehensive roadmap is needed to chart the way towards the biobased economy and allow both coherent implementation and good impact evaluation. With the enabling policy framework in place, full support then has to be given to innovation in biotechnology in general, and white biotechnology in particular. This is a research-driven activity, and Europe must build upon its strengths in the area. This means, in particular, ensuring that the various relevant Strategic Research Agendas (SRAs) from the KBBE-related Technology Platforms (particularly Sustainable Chemistry, Plants for the Future, Forestry, and Biofuels) are properly planned, funded, and implemented within the Framework 7 program and at member state level through, for instance, the European Research Area Network (ERA-Net). Within this context, it is important to foster the synergies among the various participating sectors, for example, by stimulating publicprivate partnership and industry participation in general, promoting interdisciplinary research, and striving to avoid fragmentation and duplication of programs. This cooperation must also extend downstream todemonstration projects, in particular, to enable the development of flexible, research-oriented pilot plants to validate the concept of integrated and diversified biorefineries. Appropriate funding schemes will be needed to allow multicompany consortia to collaborate in such precompetitive activities (first-of-kind biorefmeries). Moving beyond the research phase, there are practical steps which can be taken to facilitate the move towards bioprocessing in manufacturing. A necessary prerequisite is the assurance of a secure and affordable supply of biomass, for which a combination of policy, innovation, and financial incentives will be needed. With the supply of feedstock assured, conversion of existing industrial processes to biobased ones can be encouraged through streamlined regulatory processes (akin to the Fast Track system used by the US Environmental Protection Agency), assessing the opportunities for biobased processes and products to contribute and benefit from the EU's Climate Change Policy and providing market-based mechanisms to overcome investment hurdles. This manufacturing push can be further enhanced through market-pull effects. Demand can be raised in a number of ways: for example by setting appropriate public-sector procurement standards, short-term positive price discrimination, or promotional labeling of products (e.g., "biobased") . While all these actions will have a positive effect, they will be more effective if supported by a coherent communications plan to raise awareness of the potential of industrial biotechnology, the use of renewable resources, and the benefits the KBBE will bring. The plan should take account of all major stakeholders, including industry, policy makers, consumers, farmers, and the investment community, but early-stage (upstream) open engagement with the general public is particularly important. Smaller companies make up an important part of this relatively young biotechnology sector, and it is they who will provide much of the necessary innovation. Because of their early stage of development, there are a number of hurdles they find more difficult to overcome than larger companies do. Small-to-medium enterprises (SMEs) need help, in particular, to reduce the cost of intellectual property protection. Ultimately, a single European Community patent will provide the answer, but in the meantime, a specific SME application process is needed at the European Patent Office (EPO). Early-stage search costs could also be reduced by introducing a searchable database flagged for industrial biotechnology applications. While intellectual property forms the basis of innovation, finance is needed to derive value from it. Proof-of-concept work is often funded by grants for start-up companies, and SMEs could benefit from a similar grant system for work on environment-friendly technologies. More generally, greater awareness of the potential of the industrial biotechnology sector is needed among the investment community in order for funds to be made available more easily. The necessary communications program is a vital part of the overall stakeholder outreach effort. But this in itself will not be sufficient. Because of the particular difficulties of raising capital for SMEs, a new investment model will be needed which sits between loans and conventional private equity, to provide finance along with equitable risk sharing. As the industrial biotechnology sector becomes increasingly successful, venture capital will become more available. In conclusion, to establish a sustainable KBBE in Europe, efforts are needed: To establish a coherent European Policy Agenda for industrial biotechnology and the KBBE To stimulate and support innovation in plant science and industrial biotechnology To promote production and use of biobased products and processes To create awareness among all stakeholders To improve investment in KBBE-related SMEs

Anonymous (2008). "Fueling bioenergy endeavors." Resource, Engineering & Technology for a Sustainable World 15: 15-27.

The planned bioenergy-related programs and endeavors across North American colleges and universities have been summarized. The colleges and universities are addressing the need for interdisciplinary approaches to supply the growing market for renewable energy, and ASABE group members within the ivory towers are at the front. ASABE members have fostered the development of bioenergy by selecting energy and energy management as a top strategic focus. ASABE is focusing on developing an environmentally sustainable technology for biomass feedstock production, delivery, and the very processes for converting biomass to energy. ASABE is encouraging revisions to existing standards and engineering practices that relate to bioenergy, and is identifying needed new standards. Auburn University Center for bioenergy and bioproducts is emphasizing the system approaches in all research and extension efforts to develop the value added product solutions to local and community problems.

Anonymous (2009). "Economic impact of US advanced biofuels production to 2030."Industrial Biotechnology 5: 40-52.
The US Renewable Fuel Standard (RFS) for transportation fuels sets minimum levels of renewable fuels that must be blended into gasoline and other transportation fuels from 2006 to 2022. Specific requirements for blending advanced biofuels,1 including cellulosic biofuels and biomass-based diesel, begin at 0.6 billion gallons per year in 2009 and rise to 21 billion gallons in 2022. The RFS levels for advanced biofuels production will drive the creation of a major new industry, creating a foundation for future technology development and commercial growth. To estimate the economic implications of the emergence of this industry, Bio-Era conducted a meta-analysis of nearly two dozen studies of economic impacts of biofuels production, developed a model to analyze economic output and job creation, and applied this model to analyze the economic impact of increasing US advanced biofuel production to 21 billion gallons per year by 2022. This analysis yielded the following conclusions: Direct job creation from US advanced biofuels production could reach 29,000 jobs by 2012, rising to 94,000 by 2016, and 190,000 by 2022.: Total job creation, accounting for economic multiplier effects, could reach 123,000 jobs in 2012, 383,000 in 2016, and 807,000 by 2022.: Investments in advanced biofuels processing plants alone could reach dollar 3.2 billion in 2012, rising to dollar 8.5 billion in 2016, and dollar 12.2 billion by 2022.: Cumulative investment in new processing facilities between 2009 and 2022 could total more than dollar 95 billion.: Direct economic output from the advanced biofuels industry, including capital investment, research and development, technology royalties, processing operations, feedstock production, and biofuels distribution, is estimated to rise to dollar 5.5 billion in 2012, dollar 17.4 billion in 2016, and dollar 37 billion by 2022.: Taking into consideration the indirect and induced economic effects resulting from direct expenditures in advanced biofuels production, the total economic output effect for the US economy is estimated to be dollar 20.2 billion in 2012, dollar 64.2 billion in 2016, and dollar 148.7 billion in 2022.: Advanced biofuels production under the RFS scenario could reduce US petroleum imports by approximately dollar 5.5 billion in 2012, dollar 23 billion in 2016, and nearly dollar 70 billion by 2022. The cumulative total of avoided petroleum imports over the period 2010-2022 would exceed dollar 350 billion. The Bio-Era model was also used to assess the economic implications of a scenario in which total US biofuels production grows to 60 billion gallons by 2030, with 15 billion gallons of conventional biofuels production and 45 billion gallons of advanced biofuels production. This analysis concludes that: Approximately 400,000 jobs would be directly created in the advanced biofuels industry, with total employment creation in the US economy totaling 1.9 million jobs.: Direct economic output from

advanced biofuels production would rise to dollar 113 billion by 2030. The total economic output effect would be dollar 300 billion.: Biomass feedstocks in this scenario could be provided by a mix of agricultural and forest wastes and dedicated energy crops, providing a total of 470 million dry tons of biomass by 2030 using existing crop and forest land.: The average cost of advanced biofuel production at the plantgate in 2030 would be dollar 1.88/gallon, including all operating costs, overhead, and capital recovery

Azevedo, R. (2007). Ethanol and biodiesel and Brazil: standards and technical specifications. Presentation power point at the International Conference on Biofuels Standards. Baptista, Patricia. Felizardo, et al. (2008). "Multivariate near infrared spectroscopymodels for predicting the methyl esters content in biodiesel." Analytica Chimica Acta607: 153-159.
Biodiesel is one of the main alternatives to fossil diesel. It is a non-toxic renewable resource, which leads to lower emissions of polluting gases. In fact, European governments are targeting the incorporation of 20% of biofuels in the fossil fuels until 2020. Chemically, biodiesel is a mixture of fatty acid methyl esters, derived from vegetable oils or animal fats, which is usually produced by a transesterification reaction, where the oils or fats react with an alcohol, in the presence of a catalyst. The European Standard (EN 14214) establishes 25 parameters that have to be analysed to certify biodiesel quality and the analytical methods that should be used to determine those properties. This work reports the use of near infrared (NIR) spectroscopy to determine some important biodiesel properties: the iodine value, the cold filter plugging point, the kinematic viscosity at 40 degree C and the density at 15 degree C. Principal component analysis was used to perform a qualitative analysis of the spectra and partial least squares regression to develop the calibration models between analytical and spectral data. The results support that NIR spectroscopy, in combination with multivariate calibration, is a promising technique applied to biodiesel quality control, in both laboratory and industrial-scale samples.

Baptista, Patricia. Felizardo, et al. (2008). "Multivariate near infrared spectroscopy models for predicting the iodine value, CFPP, kinematic viscosity at 40 degree C and density at 15 degree C of biodiesel." Talanta 77: 144-151.
Biodiesel is one of the main alternatives to fossil diesel. It is a non-toxic renewable resource, which leads to lower emissions of polluting gases. In fact, European governments are targeting the incorporation of 20% of biofuels in the fossil fuels until 2020. Chemically, biodiesel is a mixture of fatty acid methyl esters, derived from vegetable oils or animal fats, which is usually produced by a transesterification reaction, where the oils or fats react with an alcohol, in the presence of a catalyst. The European Standard (EN 14214) establishes 25 parameters that have to be analysed to certify biodiesel quality and the analytical methods that should be used to determine those properties. This work reports the use of near infrared (NIR) spectroscopy to determine some important biodiesel properties: the iodine value, the cold filter plugging point, the kinematic viscosity at 40 degree C and the density at 15 degree C. Principal component analysis was used to perform a qualitative analysis of the spectra and

partial least squares regression to develop the calibration models between analytical and spectral data. The results support that NIR spectroscopy, in combination with multivariate calibration, is a promising technique applied to biodiesel quality control, in both laboratory and industrial-scale samples.

Bonazza, B. (2007). US biofuels standards and regulations. Presentation power point at the International Conference on Biofuels Standards. Brazil, T. T. F. "European Union, and Unites States of America." Whitepaper on Internationally Compatible Biofuel Standards. Cahill, B. (2007). European biofuels standards and regulations. Presentation power point at the International Conference on Biofuels Standards. Carlin, A. "Why a Different Approach Is Required if Global Climate Change Is to be Controlled Efficiently or Even at all." William & Mary Environmental Law and Policy Review. De Coninck, H., C. Fischer, et al. (2008). "International technology-oriented agreements to address climate change." Energy Policy 36(1): 335-356.
Much discussion has surrounded possible alternatives for international agreements on climate change, particularly post-2012. Among these alternatives, technology-oriented agreements (TOAs) are perhaps the least well defined. We explore what TOAs may consist of, why they might be sensible, which TOAs already exist in international energy and environmental governance, and whether they could make a valuable contribution to addressing climate change. We find that TOAs aimed at knowledge sharing and coordination, research, development, or demonstration could increase the overall efficiency and effectiveness of international climate cooperation, but are likely to have limited environmental effectiveness on their own. Technology-transfer agreements are likely to have similar properties unless the level of resources expended is large, in which case they could be environmentally significant. Technology-specific mandates or incentives could be environmentally effective within the applicable sector, but are more likely to make a cost-effective contribution when viewed as a complement to rather than a substitute for flexible emissions-based policies. These results indicate that TOAs could potentially provide a valuable contribution to the global response to climate change. The success of specific TOAs will depend on their design, implementation, and the role they are expected to play relative to other components of the policy portfolio.

Doraswami, U. (2008). "The European Biofuels Challenge." on 4(10): 2008-2008.
Biofuels have become a global household word due to the raging debate on their use between policymakers, non-governmental groups (NGOs), producers, public and the media. The subject was an important issue at the recent G8 summit held in Tokyo where soaring food prices and shortages held centre-stage. It also caused headlines when an article in The Guardian, quoting extracts from an unpublished World Bank Report, claimed that biofuels were responsible for hiking the food prices up by 75%.1 Biofuels have generated an array of reports and proposals from both EU governments and NGOs on the benefits versus damages that large-scale production of biofuels would cause. Europe in particular has been a quick starter in adopting biofuel targets. As part of the European Union’s (EU) ‘green’ commitment, politicians have made speedy

commitments towards technologies that seem to offer solutions to the twin problems of climate change and Europe's dependence on imported energy. However, the media have recently strongly suggested that the EU to be backpedalling on the implementation of its biofuels targets.2 However, the main reasons galvanising the growth of the European biofuel market remain unchanged. They are: rising oil prices and geopolitical undercurrents surrounding global oil production and distribution strategies; climate change; government subsidies such as Europe's Renewable Energy Sources (RES) Directive. The biofuels industry has, since its inception, drawn encouragement from government support. Yet in early July 2008, there have been suggestions of the EU backtracking on the adoption of their ambitious biofuels target. For instance, EU MEPs backed a proposal to obtain just 4% of road transport fuels from renewable sources by 2015. The 27-nation EU's official line still remains that it will adhere to the target of obtaining 10% of motor vehicle fuel from renewable sources by 2020. This forms a vital component of the overall goal of the EU to reduce carbon emissions by 20%.3 There have been growing signs from individual governments, however, that the tide supporting the biofuels industry could well be turning. The British Government has said it would 'proceed cautiously' over the introduction of biofuels, taking into account The Gallagher Report which looked at the knock-on effects of biofuel production.4 Recently there have also been reports that some French politicians have questioned the biofuels policy. Germany, for its part, has already done away with tax breaks for green fuels. Biofuels have been both seen as an alternative to fossil fuels and implicated in several studies as contributing to food shortages and an increase in food prices the world over. Due to this, their use has been passionately opposed by social and environmental groups leading to a fiery media debate on their real potential. This has also led to the formulation of certain sustainability criteria that biofuels must ideally meet. All biofuels are no longer equal. There is beginning to be a distinction between first- and second-generation biofuels. Although it will be some time before second-generation biofuels are available, these are seen as being important future contributors to the alternatives for fossil fuels. This report briefly outlines what first- and second-generation biofuels are; describes the different types of biofuels currently in use; and outlines the political and environmental reasons for their importance. It examines the drivers and obstacles to the market, outlines trends in the European market such as production heading to Eastern Europe, and analyses the media backlash and furore over the food vs. fuel debate. Additionally, the report examines the sustainability criteria for biofuels, touches on the emerging new technologies, and highlights examples of industry entrepreneurship.

Energies, W. "Overview and Recommendations on Biofuel Standards for Transport in the EU."Heinimö, J. and E. Alakangas (2006). Solid and Liquid Biofuels Markets in Finland–a study on international biofuels trade. IEA Bioenergy Task

This study considered the current situation of solid and liquid biofuels markets and international biofuels trade in Finland and identified the challenges of the emerging international biofuels markets for Finland. The fact that industry consumes more than half of the total primary energy, widely applied combined heat and power production (CHP) and a high share of biofuels in the total energy consumption are specific to the Finnish energy system. One third of the electricity is generated in CHP plants. AS much as 27% of the total energy consumption is met by using wood and peat, which makes Finland the leading country in the use of biofuels. Finland has made a commitment to maintain greenhouse gas emissions at the 1990 level at the hightest during the period 2008-2012. The Finnish energy policy aims to achieve the target, and a variety of measures are taken to promote the use of renewable energy sources and especially woodfuels.

Hess and Glenn (2006). "Push for biofuels seen in farm bill." Chemical & Engineering News 84: 29-31. Höglund, J. The Swedish fuel pellets industry: Production, market and standardization, Sveriges lantbruksuniversitet.

The production and demand for wood-based fuel pellets has increased considerably both in Sweden and internationally the recent years. Today Sweden is one of the leading nations when it comes to production and use of fuel pellets. Despite the favorable development great challenges wait. The all time high production of saw mill by-products is not enough to satisfy the growing demand for by-products, resulting in increasing raw material prices and competition. Seen in a historic context, the pellet industry has been characterized by fluctuations in supply and demand and uncertainty about how changes in governmental subsidies and the development of competitive substitutes will affect the situation. This study presents a broad overview of the Swedish pellet industry. The study had three purposes; to analyze the business situation for the producers, to examine to what extent product standards and environmental certification instruments were used within the industry, and to make an estimate on future potentials and possibilities for the pellet industry. The study was conducted in the form of a questionnaire survey to the manufacturers of fuel pellets in Sweden and the results are based on answers from 55 % of the producers, accounting for 86 % of the total production capacity. The results indicate a rapidly expanding production capacity and at the same time a strained raw material situation. The production increased with as much as 260 % from 2001 to 2007, and the planned capacity expansion totals 708 000 annual tonnes, or over 40 % of the capacity for 2007. During the same period, the competition for raw materials was getting more intense; one third of the producers experience the raw material situation as the largest threat to the production and the majority of firms have evaluated alternative raw materials in response to the increased competition. Among the alternatives examined are for example roundwood and pulp wood. The majority (47 %) of the production go to small-scale consumers. The greatest part (74 %) of all pellets manufactured are produced according to the Swedish Standard, but among the small-scale producers the use of standardization is low. More than one fifth of the production is certified according to FSC and PEFC (scarcely 300 000 tonnes). The low degree of certification depends in a first instance on the fact that 53 % of the producers do not use environmentally certified raw materials but ultimately on the low demand for environmental certified pellets. Today the pellet industry is very dependent on the demand and supply balance for other forest industry products, a dependence that in a future perspective should be abandoned in favor of alternative and forest industry independent raw materials. To avoid the risks associated with overbuilding capacity, a greater share of the Swedish production should go to the expanding international market.

Johnson and Eric (2009). "Goodbye to carbon neutral: Getting biomass footprints right." Environmental Impact Assessment Review 29: 165-168.

Most guidance for carbon footprinting, and most published carbon footprints or LCAs, presume that biomass heating fuels are carbon neutral. However, it is recognised increasingly that this is incorrect: biomass fuels are not always carbon neutral. Indeed, they can in some cases be far more carbon positive than fossil fuels. This flaw in carbon footprinting guidance and practice can be remedied. In carbon footprints (not just of biomass or heating fuels, but all carbon footprints), rather than applying sequestration credits and combustion debits, a 'carbon-stock change' line item could be applied instead. Not only would this make carbon footprints more accurate, it would make them consistent with UNFCCC reporting requirements and national reporting practice. There is a strong precedent for this change. This same flaw has already been recognised and partly remedied in standards for and studies of liquid biofuels (e.g. biodiesel and bioethanol), which now account for land-use change, i.e. deforestation. But it is partially or completely missing from other studies and from standards for footprinting and LCA of solid fuels. Carbon-stock changes can be estimated from currently available data. Accuracy of estimates will increase as Kyoto compliant countries report more land use, land use change and forestry.

Junginger, M., A. Faaij, et al. "Opportunities and barriers for sustainable international bioenergy trade and strategies to overcome them." A report prepared by IEA Bioenergy Task 40.

Trade of Biomass and Bioenergy (Biotrade) can provide a stable and reliable situation for sustainable production of biomass fuels, become a source of additional income and increased employment (e.g. for rural communities) and may contribute to the sustainable management of natural resources. For importers, biotrade may assist to fulfil GHG emission reduction targets in a costeffective manner, diversify their fuel mix and lead to a more sustainable energy production. Stimulated by the renewable energy policies in several countries, rising oil prices and a wish for diversification of supply, in most Task 40 member countries, growth rates of 10-20% per year (and above) have been observed in international trade of biomass and bioenergy. However, a multitude of different barriers currently exist, hampering the development of international bioenergy trade. These include economic, technical, logistical, ecological, social, cognitive, legal, and trade barriers, lack of clear international accounting rules and statistics, and issues regarding land availability, deforestation, energy balances, potential conflicts with food production and local use vs. international trade. To address these barriers, a number of issues have been identified for further consideration: To ensure biomass sustainability, it is recommended for actors in the various bioenergy routes both in importing and exporting countries to seek agreements on short-term (minimum) sustainability criteria, and to support a long-term development of international standards for important and generally accepted issues. Some of the Task 40 members advocate an international certification system for biomass embedded in (inter)national regulations, while others would preferably see a voluntary approach. For market transparency, Task 40 recommends to the IEA, UNCTAD, WTO and national trade organisation to include (new) biomass types in their statistics, and to include the final application (e.g. energy, chemical feedstock, fodder etc.) where possible. Furthermore, it is recommended that the various standards that are applied today are developed into internationally accepted quality standards for specific biomass streams (e.g. CEN biofuel standards). To stimulate international trade, Task 40 identifies import barriers for certain biomass and biofuels types to be a major obstacle for a smooth further development of international bioenergy trade. Some Task members emphasise that on the short-term, local industries should also be given the opportunity to develop innovative and improved processes for biomass and biofuels production. Other task members stress that such a process should be coupled to a phase-out agenda with clearly defined quotas.

Kaltschmitt, Martin. Weber, et al. (2006). "Markets for solid biofuels within the EU-15." Biomass & Bioenergy 30: 897-907.
Biomass is seen as a very promising option for fulfilling the environmental goals defined by the European Commission as well as various national governments. The goal of this paper is to analyse the possibilities for energy provision from biomass in general and from solid biofuels in particular. The potentials of solid biofuels as well as their current use is analysed and discussed in the context of the overall energy system. The result of this analysis shows that there are still unused potentials, which can contribute significantly to cover the energy demand within the EU-15. The most important markets for solid biofuels are analysed in detail; markets for solid biofuels with low, medium, and large variations of fuel properties. This investigation shows that biofuels with essentially uniform fuel properties have shown the most impressive market developments in recent years. The main prerequisite to achieve this significant growth in market volume has been standardisation of the fuel properties. Therefore biofuel standardisation is seen as a major key issue to develop the markets.

Kaphengst, T., M. S. Ma, et al. (2009). "At a tipping point? How the debate on biofuel standards sparks innovative ideas for the general future of standardisation and certification schemes." Journal of Cleaner Production.
Consumer demand for environmentally and socially responsible products is the driving force behind the expansion of competing certification systems. Paradoxically, this has led to an increasingly crowded marketplace for labels and confusion among stakeholders such as producers, retailers and buyers, rather than providing clear and reliable product information as intended. The situation has sparked a debate about the future of certification schemes and the need for a more streamlined system. This article explores some of the innovative ideas coming from the current discussion regarding biofuel certification and standardisation and outlines how those ideas can be applied to create a

global generic standard-setting scheme for natural resources.

Knoef, H. and J. Ahrenfeldt (2005). Handbook biomass gasification, BTG Biomass Technology Group.
The Handbook on Biomass Gasification is meant to disseminate the results of the European Gasification Network (GasNet) to a wider audience, which started in 2001 with funding of DG TREN. The gasification network was clustered to the pyrolysis network, comprising the Thermonet project with 36 members of all EU countries including Switzerland. Each Network had its own work programme, but both ha also a common focus of addressing commercialisation issues and providing support for more rapid and more effective implementation of all the technologies in the market place. The Handbook describes specific topic discussed thoroughly within GasNet and additional chapters on more general aspects of biomass gasification including gasification of pyrolysis oil, market assessments, economics, legislative impacts, health and safety, tar standardisation and incentives for bio-energy through gasification. Authors and co-authors have been invited to contribute in various

Korbitz and W (1999). "Biodiesel production in Europe and North America, an encouraging prospect." Renewable energy 16: 1-4.
As used already by Rudolf Diesel in 1912 plant oils represent not a new alternative fuel compared to fossil sources, but only by the force of the oil supply shocks in the 70s a new development of Biodiesel was triggered. This paper gives a review of the political background, the historical development since the beginnings in Austria and the volumes produced today in the world, the main raw materials used, key fuel properties and standards. It highlights the fuel's environmental advantages and different marketing strategies applied as well as key factors of micro- and macro-economic considerations.

Liska, Adam J. Cassman, et al. (2008). "Towards standardization of life-cycle metrics for iofuels: Greenhouse gas emissions mitigation and net energy yield." Journal of iobased Materials & Bioenergy 2: 187-203. aniatis, K. (2007). EC Policy on biofuels specifications. Presentation power point at he International Conference on Biofuels Standards.Market, S. B. "Technical Specifications for Solid Biofuels."
Belbo, H. 2006. Technical Specifications for Solid Biofuels. Evaluation of the new echnical Specifications provided by CEN/TC 335 in the Swedish Biofuel Market. asters Thesis. The main objective of this thesis was to determine to which xtent the new terminology standard and fuel specification standard provided by he European Committee for Standardization (CEN) have penetrated the wedish biofuel market and to which extent they fit the need of its users. Two urveys and six interviews were performed. One survey was addressed to large cale producers, suppliers and consumers of solid biofuels, the other survey was dressed to producers and suppliers of equipment for upgrading and ombustion of solid biofuels. The interviewees were actors from different stages n the biofuel supply chain: 1) Medium-scale log wood producer; 2) Large scale roducer and supplier of solid woodfuels for large scale consumers; 3) Large cale straw firing DH-plant;

4) Actor providing measurement services of larges cale biofuel deliveries; 5) Large scale producer of upgraded solid biofuels. esults from the surveys indicate that ca two thirds of the biofuel actors and one hird of the equipment producers know about the existence of at least one of the entioned standards. Still only a few of the respondents use any of the standards. Some nonconformity between information required by the biofuel factors and information provided of the standards was discovered. Net calorific value is highly demanded by both producers and consumers and should be obligatory information for most kinds of solid biofuels. Content of heavy metals and Cesium 137 should be stated if it is high enough to cause risk for restrictions regarding ash recycling in crop land and forest. Ash melting temperature is demanded for many kinds of fuels and ash melting is seen as a problem causing wear and stoppages by 80% of the respondents making combustion equipment. Some of the interviewees were sceptical to the idea of several threshold values on the different fuel properties. Many of the threshold values is suggested to be rejected, except from cases where they are motivated by restrictions regarding contamination of ash, risk for air emissions or where solid biofuels are intended for usage by unskilled people at household level. Key words: Solid biofuels, standards, fuel quality Author’s address: Helmer Belbo, Department of Bioenergy, SLU, P.O. Box 7061

Mildner, S. and O. Ziegler (2009). "A Long and thorny road." Intereconomics 44(1): 49-58.

When the European Union and the United States agreed on the Framework for Advancing Transatlantic Economic Integration at the EU-US Summit on 30 April 2007, creating the Transatlantic Economic Council (TEC), they praised themselves for opening a new era in transatlantic regulatory cooperation. Transatlantic integration and growth were said to be enhanced and efforts to reduce barriers to transatlantic trade and investment redoubled. However, after two meetings of the TEC with only modest achievements, enthusiasm has faded quickly and finger pointing has begun anew. What went wrong?

Obernberger, Ingwald. Brunner, et al. (2006). "Chemical properties of solid biofuelssignificance and impact." Biomass & Bioenergy 30: 973-982.

The chemical composition of solid biofuels (as defined in left bracket Directive 2000/76/EC of the European Parliament and of the Council on the Incineration of Waste. In: European Commission, editor. Official Journal of the European Communities, vol. L 332; 2000. p. 91-111 right bracket and left bracket CEN/TC 335-WG2 N94. Final draft. European Committee for standardization, editor. Solid biofuels-fuel specifications and classes. Brussels, Belgium; 2003. right bracket has manifold effects on their thermal utilisation. C, H and O are the main components of solid biofuels and are of special relevance for the gross calorific value, H in addition also for the net calorific value. The fuel N content is responsible for NOx formation. NOx emissions belong to the main environmental impact factors of solid biofuel combustion. Cl and S are responsible for deposit formation and corrosion and are therefore relevant for a high plant availability. Furthermore, Cl causes HCl as well as PCDD/F and S SOx emissions and both elements are involved in the formation of aerosols (submicron particle emissions). The ash content influences the choice of the appropriate combustion technology and influences deposit formation, fly ash emissions and the logistics concerning ash storage and ash utilisation/disposal. Major ash forming elements (Al, Ca, Fe, K, Mg, Na, P, Si, Ti) are of relevance for the ash melting behaviour, deposit formation and corrosion. In addition, volatile elements such as Na and K are main constituents of aerosols. Volatile minor elements (As, Cd, Hg, Pb, Zn) play a major role in gaseous and especially aerosol emissions as well as in deposit formation, corrosion and ash utilisation/disposal. Either partly or non-volatile minor elements (Ba, Co, Cr, Cu, Mo, Mn, V) are of special relevance for ash utilisation. The present paper discusses the influence of chemical fuel properties on biomass combustion plants as well as possibilities and recommendations for controlling them.

Purvis, N. (2004). Climate Change and the L20 Options for Non-Emission Target Commitments, Post-Kyoto Architecture: Toward an L.

Iodine value (IV) limitation of biodiesel is currently one of the most discussed topics within the different world-wide biofuel specifications. Claims concerning engine operability on high IV feedstocks and biodiesel are interrelated. Also, the limitation of feedstock is a major problem for producers as well as for biodiesel trade. In this context, it might be time to re-evaluate the IV parameter. Based on available data, reports, and experience in this field the enclosed considerations maybe will help to answer the (admittedly provocative) question: Is IV limitation still appropriate?

Quotas, W., T. Continues, et al. (2009). "REFERENCES TO OTHER TOPICS." Environmental Policy and Law 39(1): 75-76. UNEP: Development of Biofuels Standards UNEP is in the process of obtaining global stakeholder... Rao, Y. (2007). Biofuels Standards and Regulation in India. Presentation power point at the International Conference on Biofuels Standards. Ribeiro, Nubia. Pinto, et al. (2007). "The role of additives for diesel and diesel blended (ethanol or biodiesel) fuels: A review." Energy & Fuels 21: 2433-2445.

Around the world, there is a growing increase in biofuels consumption, mainly ethanol and biodiesel as well as their blends with diesel that reduce the cost impact of biofuels while retaining some of the advantages of the biofuels. This increase is due to several factors like decreasing the dependence on imported petroleum; providing a market for the excess production of vegetable oils and animal fats; using renewable and biodegradable fuels; reducing global warming due to its closed carbon cycle by CO2 recycling; increasing lubricity; and reducing substantially the exhaust emissions of carbon monoxide, unburned hydrocarbons, and particulate emissions from diesel engines. However, there are major drawbacks in the use of biofuel blends as NOx tends to be higher, the intervals of motor parts replacement such as fuel filters are reduced and degradation by chronic exposure of varnish deposits in fuel tanks and fuel lines, paint, concrete, and paving occurs as some materials are incompatible. Here, fuel additives become indispensable tools not only to decrease these drawbacks but also to produce specified products that meet international and regional standards like EN 14214, ASTM D 6751, and DIN EN 14214, allowing the fuels trade to take place. Additives improve ignition and combustion efficiency, stabilize fuel mixtures, protect the motor from abrasion and wax deposition, and reduce pollutant emissions, among other features. Two basic trends are becoming more relevant: the progressive reduction of sulfur content and the increased use of biofuels. Several additives' compositions may be used as long as they keep the basic chemical functions that are active.

Rotman, D. (2008). "New federal biofuel standards will distort the development of innovative energy technologies." TECHNOLOGY REVIEW-MANCHESTER NH- 111(2): 90-90. Rusco, F. W., W. D. Walls, et al. "BIOFUELS, PETROLEUM REFINING, AND THE SHIPPING OF MOTOR FUELS."

A number of Asian and European countries, the U.S. federal government, and numerous individual U.S. states and localities have proposed or mandated use of biofuels—such as ethanol made from corn or biodiesel made from soybeans or other crops—partly in an effort to reduce greenhouse gas emissions and reduce consumption of petroleum products. These mandates call for biofuels to be blended in varying proportions with traditional gasoline or diesel and, in some cases, allow or require different biofuel standards. To maintain engine performance and emissions requirements, varying biofuel blends and standards will require changes to gasoline and diesel blendstocks that biofuels are mixed with. The manufacture of these different blendstocks will require modifications to the refining infrastructure. In addition, changes to blendstocks will further balkanize the mix of liquid fuels and put additional strain on an already stressed pipeline and storage infrastructure as smaller batches of incompatible fuels are shipped to an increasing number of locations. Further, because biofuels will typically be produced near the bio-feedstocks—which are currently not typically served by pipeline systems—trucking, rail, and barge infrastructure may expand until and unless new pipelines are built. Finally, the different blendstocks required for different regions will reduce the fungibility of petroleum liquid fuels, thereby reducing trade and increasing price volatility, similar to the effects in the United States of a proliferation of gasoline blends in response to Clean Air Act air quality standards. These and other unintended effects and additional capital expenditures raise serious questions about the efficacy of rapid expansion of biofuel use and also call for policy makers to consider negotiating biofuel production and blending standards to reduce the eventual number of incompatible liquid fuels.

Rutz, D. (2007). "BioFuel SWOT-Analysis." WIP Renewable Energies–2007 1.

In times of shrinking fossil energy resources, biofuels are a visible alternative for satisfying today’s transport needs. Among many others, the main advantages of biofuels are their potential to reduce greenhouse gas emissions and their contribution to secure energy supply. On the other hand, the production of biofuels is land and cost intensive. In order to get an overview of advantages and disadvantages of biofuels, a SWOT analysis was conducted in the framework of the project Biofuel Marketplace. This analysis addresses biofuels in comparison with fossil fuels and in comparison with each other. It will serve as a basic document for creating a favorable policy framework to promote biofuels. The project Biofuel Marketplace (www.biofuelmarketplace.com) provides a biofuel information portal combined with a supply and demand information system (a web-based biofuel marketplace) in order to provide a forum where Europe's biofuel stakeholders can promote their technologies, exchange ideas, sell and buy biofuel products, disseminate results of national, international and European research activities and raise awareness of the public and the professional community. Recent European advances, projects, products, results and patents are screened at strategic, management and technological levels and the commercially feasible results of European initiatives are fed into the Biofuel Marketplace to be made available for all European stakeholders through the project website.

Rutz, D. and R. Janssen (2006). Overview and Recommendations on Biofuel Standards for Transport in the EU, WIP Renewable Energies.
His report gives an overview on biofuel standards for transport in the European Union. It will outline the most recent developments in biofuel standardisation to inform producers of biofuels and related technologies, traders, politicians and other stakeholders who are inter-ested in this subject. With the advancement and expansion of the European Union, generally the role of national standards has been increasingly taken over by international standards, primarily European standards. These European standards are developed by the European Committee for Stan-dardization (CEN). As the market share of biofuels increased considerably in the last few years, the need for specifications and standards of these biofuels has been highlighted by stakeholders and authorities. Consequently large efforts have been made on biofuel standardisation in the European Union: since 2003 a common European standard for biodiesel exists. Also the standardisation for bioethanol proceeded. The Technical Committee number 19 of CEN is working very hard to issue a common European standard for bioethanol. A first draft is already publicly available. The development and implementation of standardisations diminishes trade barriers, pro-motes safety, increases compatibility of products, systems and services, and promotes common technical understanding. All standards help build the 'soft infrastructure' of mod-ern, innovative economies. They provide certainty, references, and benchmarks for design-ers, engineers and service providers. They give 'an optimum degree of order' (CEN 2006). Thus standards are of vital importance for producers, suppliers and users of biofuels. A standard is a prerequisite for the market introduction and commercialisation of new fuels.

Samson, R., S. B. Stamler, et al. (2008). "Analysing Ontario biofuel options: Greenhouse gas mitigation efficiency and costs." BIOCAP Foundation of Canada, prepared by REAP Canada. online: Biocap Canada< http://www. biocap. ca/reports/BIOCAP-REAP_bioenergy_policy_incentives. pdf.
Fuels made from biological feedstocks rather than coal, oil or natural gas have attracted widespread interest from policy makers, investors and consumers. A key attraction of biofuels is the promise to address priorities such as energy security, climate change and rural economic development. In recent years, concerns about climate change have taken

centre stage, dominating the press, affecting elections in Australia, and winning former U.S. Vice-President Al Gore both an Oscar for Best Documentary Film and the 2007 Nobel Peace Prize. Given the current importance of the climate change issue, this study compares the cost effectiveness of various alternative energy policy incentives in mitigating greenhouse gas emissions in the Province of Ontario. The report concludes that solid biofuels offer the least expensive biofuel strategy for government incentives to reduce greenhouse gas emissions in the province of Ontario.

Schober, S. and M. Mittelbach (2007). "Iodine value and biodiesel: Is limitation still appropriate?" Lipid Technology 19(12).
Iodine value (IV) limitation of biodiesel is currently one of the most discussed topics within the different world-wide biofuel specifications. Claims concerning engine operability on high IV feedstocks and biodiesel are interrelated. Also, the limitation of feedstock is a major problem for producers as well as for biodiesel trade. In this context, it might be time to re-evaluate the IV parameter. Based on available data, reports, and experience in this field the enclosed considerations maybe will help to answer the (admittedly provocative) question: Is IV limitation still appropriate?

Spatari, S. and K. Fingerman (2008). "Sustainability and the Low Carbon Fuel Standard." Research Report for the California Air Resources Board, in preparation.
Sustainability and the Low Carbon Fuel Standard Sabrina Spatari1,3, Michael O'Hare2, Kevin Fingerman1, Daniel Kammen1,2, Alex E. Farrell1 1Energy and Resources Group 2Goldman School of Public Policy University of California, Berkeley 9/X/08 3corresponding author: spatari@berkeley.edu Executive Summary To reduce global warming and in pursuit of other goals, renewable fuel standards (RFS's) in Canada, the UK, Germany, and elsewhere, and the California low carbon fuel standard (LCFS), directly or implicitly require blenders of transportation fuels to use fuel components such as bioethanol in their products. These components must be shown to have lower GHG emissions than conventional petroleum on the basis of life cycle assessment (LCA). Most of these programs go beyond mitigating climate change by addressing a broad set of criteria that are intended to support social, economic, and ecological welfare, loosely categorized under the word sustainability. Environmental, economic and social sustainability criteria can be inferred from three main sources: the academic literature; government frameworks aimed at setting sustainability policies for biofuels; and non-government organizations supporting development of biofuels that meet their preferred set of sustainability criteria. We develop a set of operational definitions of especially important sustainability criteria for biofuels, and from this a list of possible sustainability reporting requirements for the LCFS in near and longer-term time frames: • carbon storage, • biodiversity conservation, • soil conservation, • sustainable water use, • air pollution, • food security, • labor issues, and • land rights issues. Since unconventional petroleumbased fuels, primarily those developed from the Canadian oil sands, are expected to also gain market share in coming years, we also examine fuel production sustainability metrics

and reporting requirements for those fuels. The dimensionality, local specificity, and data demands for an integrated assessment of sustainability usable in the LCFS (and by implication, in other RF programs as well) are daunting. We discuss implementation structures by which a regulator could include these dimensions of fuel performance and find that at this point Spatari et al 9-X-08 p. 2 existing knowledge is too weak for sustainability standards to be designed with sufficient robustness, and might require regulators to adopt a disclosure-only monitoring program, with the consideration of regulating in the future. 1.0 Introduction

Stapel, C. (2007). Vehicle Emissions as a Basis for Fuel Specifications. International Conference on Biofuels Standards, European Commission, Bruxelles, February.
Tan, Raymond R. Culaba, et al. (2002). "Application of possibility theory in the life-cycle inventory assessment of biofuels." International Journal of Energy Research 26: 737- 745.
Data uncertainty issues have constrained the widespread acceptance of life-cycle analysis (LCA) and related methods. This is particularly important in the LCA of fuels due to the wide range of available feedstocks and processing options. Despite recent attempts at standardization, there remain persistent doubts about the general validity of LCA results, often due to uncertainties about data quality. This paper demonstrates the application of possibility theory as a tool for handling life-cycle inventory data imprecision for the case of the net energy balance of coconut methyl ester (CME) as a biodiesel transport fuel. Results derived using a possibilistic computation are contrasted with those arrived at by probabilistic (Monte Carlo) simulation. The two approaches yield comparable results but possibilistic modelling offers significant advantages with respect to computational efficiency. The net energy balance of CME is estimated to be approximately 36 MJ kg-1, significantly higher than the 28 MJ kg-1 net energy typical of rapeseed oil methyl ester (RME) relevant to the U.K

Temmerman, Michael. Rabier, et al. (2006). "Comparative study of durability test methods for pellets and briquettes." Biomass & Bioenergy 30: 964-972.
Different methods for the determination of the mechanical durability (DU) of pellets and briquettes were compared by international round robin tests including different laboratories. The DUs of five briquette and 26 pellet types were determined. For briquettes, different rotation numbers of a prototype tumbler and a calculated DU index are compared. For pellets testing, the study compares two standard methods, a tumbling device according to ASAE S 269.4, the Lignotester according to ONORM M 7135 and a second tumbling method with a prototype tumbler. For the tested methods, the repeatability, the reproducibility and the required minimum number of replications to achieve given accuracy levels were calculated. Additionally, this study evaluates the relation between DU and particle density. The results show for both pellets and briquettes, that the measured DU values and their variability are influenced by the applied method. Moreover, the variability of the results depend on the biofuel itself. For briquettes of DU above 90%, five replications lead to an accuracy of 2%, while 39 replications are needed to achieve an accuracy

of 10%, when briquettes of DU below 90% are tested. For pellets, the tumbling device described by the ASAE standard allows to reach acceptable accuracy levels (1%) with a limited number of replications. Finally, for the tested pellets and briquettes no relation between DU and particle density was found.

Thephun, P. (2007). Biofuels Standards and Regulation in Thailand. Presentation power point at the International Conference on Biofuels Standards. Tian, Y. S., L. X. Zhao, et al. (2007). "Status of solid biofuel standards of EU." Kezaisheng Nengyuan(Renewable Energy Resources) 25(4): 61-64

So far, EU has established a solid biofuels standard system, which includes five aspects such as terminology; specifications and classes, and quality assurance; sampling and sample reduction; Physical (or mechanical) test; chemical test and etc., 26 technical regulations have been issued. At present, China still lacks solid biomass fuel standards. Therefore, learning from the European Union standard, and building our solid biomass fuels standard system are of great significance. So far, EU has established a solid biofuels standard system, which includes five aspects such as terminology; specifications and classes, and quality assurance; sampling and sample reduction; Physical (or mechanical) test; chemical test and etc., 26 technical regulations have been issued. At present, China still lacks solid biomass fuel standards. Therefore, learning from the European Union standard, and building our solid biomass fuels standard system are of great significance.

Tripartite, T. F. and E. U. A. Ue (2007). White Paper on Internationally Compatible Biofuel Standards, December.

This report gives an overview of standardisation of solid biofuels and of equipment for biofuel utilisation as well as ideas and proposals for development of additional standards related to the bioenergy field. Existing standards have been analysed for their suitability in biofuel trade and usage. During this analysis and in contacts with numerous biofuel professionals, needs and ideas for further standards wer identifed and collected. Included are short summaries of both published standards and standards under development in Europe. The European organisation for standardisation, CEN, is in the process of develping a whole seriew of standards for solid biofuels. There are also CEN equipment standards and guidelines, both published and under development. Beside DEN standards there are national standards in most countries. A short description of each standard is presented including contact information.

Türk, A., H. Schwaiger, et al. "AN ASSESSMENT OF TRADING MECHANISMS AS A METHOD FOR INCREASING LIQUID BIOFUELS IN THE ROAD TRANSPORT SECTOR."

The road transport sector is currently excluded from the EU-ETS and is unlikely to be included until 2020. Abatement costs for biofuel-related measures in the transport sector are higher than in other sectors. Therefore an inclusion into the EU-ETS represents a risk that transportation companies will purchase allowances from other sectors, leading to higher CO_2 prices within the EU-ETS. This would also reduce incentives to mitigate emissions in the transport sector itself. Policy options include regulation, market based instruments such as emissions trading and provision of information. Policy makers will need to decide whether to focus on limiting emissions from the transport sector or to increase use of biofuels. A cap & trade scheme would be the appropriate instrument to reduce emissions. To increase biofuel use, regulation would be the appropriate instrument. Inclusion of emission reductions from the transportation sector via a baseline & credit approach would favor biofuels and could lead to more flexibility and lower costs. Such an approach could also be specially designed to address issues of sustainability and to accelerate the implementation of new technologies. This approach was taken in California and this paper illustrates that it could also be the way forward for the EU.

Wiesenthal, T., G. Leduc, et al. (2009). "Biofuel support policies in Europe: Lessons learnt for the long way ahead." Renewable and Sustainable Energy Reviews 13(4): 789-800.

Biofuel consumption in the EU is growing rapidly but major efforts will need to be undertaken if the EU's objectives for 2010 and beyond are to be achieved. This article analyses the strengths and weaknesses of different biofuel support policies based on the experiences gained in pioneering countries and explores scenarios for their possible impacts in the long-term. It comes to the conclusion that important pre-conditions such as fuel standards and compatibility with engines are in place or being introduced on an EU-wide basis. Current and future policy support therefore focuses on creating favourable economic or legal frameworks to accelerate the market penetration of biofuels. The ambitious targets endorsed in terms of biofuel market shares require the implementation of efficient policy instruments. At the same time, large consumption volumes and the advent of innovative production technologies make it possible for Member States to promote specific types of biofuels, depending on their main objectives and natural potentials. This will require complementary instruments such as subsidies for production facilities, user incentives or feedstock subsidies.

Yamane and Koji (2006). "Trends and future of biofuels." Review of Automotive Engineering 27: 039-047.

Despite a rapid worldwide expansion of the biofuel industry, there is a lack of consensus within the scientific community about the potential of biofuels to reduce reliance on petroleum and decrease greenhouse gas (GHG) emissions. Although life cycle assessment provides a means to quantify these potential benefits and environmental impacts, existing methods limit direct comparison within and between different biofuel systems because of inconsistencies in performance metrics, system boundaries, and underlying parameter values. There is a critical need for standardized life-cycle methods, metrics, and tools to evaluate biofuel systems based on performance of feedstock production and biofuel conversion at regional or national scales, as well as for estimating the net GHG mitigation of an individual biofuel production system to accommodate impending GHG-intensity regulations and GHG emissions trading. Predicting the performance of emerging biofuel systems (e.g., switchgrass; cellulosic ethanol) poses additional challenges for life cycle assessment due to lack of commercialscale feedstock production and conversion systems. Continued political support for the biofuel industry will be influenced by public perceptions of the contributions of biofuel systems towards mitigation of GHG emissions and reducing dependence on petroleum for transportation fuels. Standardization of key performance metrics such as GHG emissions mitigation and net energy yield are esservtial to help inform both public perceptions and public policy.

Bibliography Biofuels Conversion Technologies

Anaerobic Digestion Adam J. Liska, H. S. Y., Virgil R. Bremer, Terry J. Klopfenstein, Daniel T. Walters, Galen E. Erickson, Kenneth G. Cassman, (2009). "Improvements in Life Cycle Energy Efficiency and Greenhouse Gas Emissions of Corn-Ethanol." Journal of Industrial Ecology 13(1): 58-74.
Corn-ethanol production is expanding rapidly with the adoption of improved technologies to increase energy efficiency and profitability in crop production, ethanol conversion, and coproduct use. Life cycle assessment can evaluate the impact of these changes on environmental performance metrics. To this end, we analyzed the life cycles of corn-ethanol systems accounting for the majority of U.S. capacity to estimate greenhouse gas (GHG) emissions and energy efficiencies on the basis of updated values for crop management and yields, biorefinery operation, and coproduct utilization. Direct-effect GHG emissions were estimated to be equivalent to a 48% to 59% reduction compared to gasoline, a twofold to threefold greater reduction than reported in previous studies. Ethanol-to-petroleum output/input ratios ranged from 10:1 to 13:1 but could be increased to 19:1 if farmers adopted high-yield progressive crop and soil management practices. An advanced closed-loop biorefinery with anaerobic digestion reduced GHG emissions by 67% and increased the net energy ratio to 2.2, from 1.5 to 1.8 for the most common systems. Such improved technologies have the potential to move corn-ethanol closer to the hypothetical performance of cellulosic biofuels. Likewise, the larger GHG reductions estimated in this study allow a greater buffer for inclusion of indirect-effect land-use change emissions while still meeting regulatory GHG reduction targets. These results suggest that corn-ethanol systems have substantially greater potential to mitigate GHG emissions and reduce dependence on imported petroleum for transportation fuels than reported previously.

Ihrig, D. F., H. M. Heise, et al. (2008). "Combination of biological processes and fuel cells to harvest solar energy." Journal of Fuel Cell Science & Technology 5.
Biomass production bc micro-algae is by a factor of 10 more efficient than by plants, by which an economic process of solar energy harvesting can be established. Owing to the very low dry mass content of algal suspension, the most promising way of their conversion to a high exoergic and transportable form of energy is the anaerobic production of biogas. On account of this, we are developing such processes including a micro-algal reactor methods for microalgal cell separation and biomass treatment, and a subsequent two-stage anaerobic fermentation process. First results from parts of this development work are shown. The continuous feeding of the anaerobic process over several weeks using micro-algal biomass is discussed in more details. The biogas is composed

of methane, higher hydrocarbons, carbon dioxide, and hydrogen sulphide. Using steam reforming, it can be converted to a mixture of carbon dioxide and hydrogen. These gases can be separated using membrane technology. It is possible to form a closed carboncycle by recycling the carbon dioxide to the micro-algal process. The transportable and storable hydrogen product is a valuable energy source and can he converted to electrical energy and heat using fuel cells. The simulation of such a process will be explicated. Copyright copy 2008 by ASME.

Cofiring Blevins, L. G. and T. H. Cauley Iii (2005). "Fine particulate formation during switchgrass/coal cofiring." Journal of Engineering for Gas Turbines & Power 127(3): 457-463.
Experiments to examine the effects of biomass/coal cofiring on fine particle formation were performed in the Sandia Multi-Fuel Combustor using fuels of pure coal, three combinations of switchgrass and coal, and pure switchgrass. For this work, fine particles with aerodynamic diameter between 10 mn and 1 mum were examined. A constant solid-fuel thermal input of 8 kW was maintained. The combustion products were cooled from 1200 to 420 degree C during passage through the 4.2 m long reactor to simulate the temperatures experienced in the convection pass of a boiler. Fine particle number densities, mass concentrations, and total integrated number and mass concentrations at the reactor exit were determined using a scanning mobility particle sizer The fine particle number concentrations for cofiring were much higher than those achieved with dedicated coal combustion. However, the total integrated mass concentration of particles remained essentially constant for all levels of cofiring from 0% coal to 100% coal. The constant mass concentration is significant because pending environmental regulations are likely to be based on particle mass rather than particle size. Copyright copy 2005 by ASME.

Boylan, D., S. Wilson, et al. (2001). Evaluation of Switchgrass Co-firing for Utility Boiler Applications. Proceedings of the International Joint Power Generation Conference.
A study is being conducted by Southern Company, Southern Research Institute, EPRI and the US Department of Energy to evaluate the feasibility, costs, and benefits of co-firing switchgrass with coal in existing coal-fired power plants. Switchgrass is a highly productive prairie grass native to the United States. The grass can be grown on marginal land, requires little fertilization and weed control, and can be maintained and harvested with standard farm equipment. Energy production from a renewable biomass fuel offers reduced emissions, including CO2, NOx, and SO2, as well as agri-business benefits. The program includes farm, pilot-scale combustor, and full-scale power plant studies. Three hundred acres of Alabama farmland have been planted with switchgrass, and costs and techniques of grass production, harvesting options, handling, and preparation are being evaluated. To evaluate the possibility of co-milling coal and grass, studies were conducted at Southern Company's pilot combustion facility to investigate the milling properties of the mixtures. Combustion studies, also conducted at the pilot facility, measured the effects of co-firing methods and quantities on emissions, combustion stability, unburned carbon, and slagging and fouling. Results have been obtained on field processing and handling issues, as well as farm production costs. Pilot-scale tests of co-milling and combustion of blends of switchgrass with coal have been successfully completed. An additional phase of work yet to be completed is full-scale testing of switchgrass co-firing in a 60 MW power plant boiler. For these tests, a pneumatic injection system was designed and constructed at the

site. In on-going testing, switchgrass is being conveyed at up to 10% of the total heat input through this system and introduced into the boiler separately from the coal. Testing is scheduled to be completed by mid- 2001.

Morrow, W. R., W. M. Griffin, et al. (2008). "National-level infrastructure and economic effects of switchgrass cofiring with coal in existing power plants for carbon mitigation." Environmental Science & Technology 42(10): 3501-3507.
We update a previously presented Linear Programming (LP) methodology for estimating state level costs for reducing CO2 emissions from existing coal-fired power plants by cofiring switchgrass, a biomass energy crop, and coal. This paper presents national level results of applying the methodology to the entire portion of the United States in which switchgrass could be grown without irrigation. We present incremental switchgrass and coal cofiring carbon cost of mitigation curves along with a presentation of regionally specific cofiring economics and policy issues. The results show that cofiring 189 million dry short tons of switchgrass with coal in the existing U.S. coal-fired electricity generation fleet can mitigate approximately 256 million short tons of carbon-dioxide (CO2) per year, representing a 9% reduction of 2005 electricity sector CO2 emissions. Total marginal costs, including capital, labor, feedstock, and transportation, range from dollar 20 to dollar 86/ton CO2 mitigated, with average costs ranging from dollar 20 to dollar 45/ton. If some existing power plants upgrade to boilers designed for combusting switchgrass, an additional 54 million tons of switchgrass can be cofired. In this case, total marginal costs range from dollar 26 to dollar 100/ton CO2 mitigated, with average costs ranging from dollar 20 to dollar 60/ton. Costs for states east of the Mississippi River are largely unaffected by boiler replacement; Atlantic seaboard states represent the lowest cofiring cost of carbon mitigation. The central plains states west of the Mississippi River are most affected by the boiler replacement option and, in general, go from one of the lowest cofiring cost of carbon mitigation regions to the highest. We explain the variation in transportation expenses and highlight regional cost of mitigation variations as transportation overwhelms other cofiring costs. copy 2008 American Chemical Society.

Styles, D. and M. B. Jones (2007). "Energy crops in Ireland: Quantifying the potential life-cycle greenhouse gas reductions of energy-crop electricity." Biomass & Bioenergy 31(11-12): 759-772.
This study uses life-cycle assessment (LCA) to compare greenhouse gas (GHG) emissions from dominant agricultural land uses, and peat and coal electricity generation, with fuel-chains for Miscanthus and short-rotation-coppice willow (SRCW) electricity. A simple scenario was used as an example, where 30% of peat and 10% of coal electricity generation was substituted with co-fired Miscanthus and SRCW, respectively. Miscanthus and SRCW cultivation were assumed to replace sugar-beet, dairy, beef-cattle and sheep systems. GHG emissions of 1938 and 1346 kg CO2 eq. ha-1 a-1 for Miscanthus and SRCW cultivation compared with between 3494 CO2 eq. ha-1 a-1 for sugar-beet cultivation and 12,068 CO2 eq. ha-1 a-1 for dairy systems. Miscanthus and SRCW fuel chains emitted 0.131 and 0.132 kg CO2 eq. kWh-1 electricity exported, respectively, compared with 1.150 and 0.990 kg CO2 eq.

kWh-1 electricity exported for peat and coal fuel chains. 1.48 Mt CO2 eq. a-1 was saved from electricity production, and 0.42 Mt CO2 eq. a-1 was saved from displaced agriculture and soil C-sequestration. The total reduction of 1.9 Mt CO2 eq. a-1 represents 2.8% of Ireland's 2004 GHG emissions, but was calculated to require just 1.7% of agricultural land area and displace just 1.2% of the dairy herd (based on conservative Miscanthus and SRCW combustible-yield estimates of 11.7 and 8.81 t ha-1 a-1 dry matter, respectively). A 50% increase in cultivation emissions would still result in electricity being produced with an emission burden over 80% lower than peat and coal electricity. Lower yield assumptions had little impact on total GHG reductions for the scenario, but required substantially greater areas of land. It was concluded that energy-crop utilisation would be an efficient GHG reduction strategy for Ireland. copy 2007 Elsevier Ltd. All rights reserved.

Combustion

L., B. L., M. T. R., et al. (1998). "The behavior of inorganic material in biomass-fired power boilers: Field and laboratory experiences." Fuel Process. Technol. 54: 47. L., T., S. R., et al. (2007). "Deposit characteristic after injection of additives to a Danish strawfired suspension boiler." Fuel Process. Technol. 88: 1108. N., K. J., J. P. A., et al. (2004). "Transformation and release to gas phase of Cl, K and S during combustion of annual biomass." Energy Fuels 18: 1385. Roth, A. M., D. W. Sample, et al. (2005). "Grassland bird response to harvesting switchgrass as a biomass energy crop." Biomass & Bioenergy 28(5): 490-498.

The combustion of perennial grass biomass to generate electricity may be a promising renewable energy option. Switchgrass (Panicum virgatum) grown as a biofuel has the potential to provide a cash crop for farmers and quality nesting cover for grassland birds. In southwestern Wisconsin (near lat. 42 degree 52 prime , long. 90 degree 08 prime), we investigated the impact of an August harvest of switchgrass for bioenergy on community composition and abundance of Wisconsin grassland bird species of management concern. Harvesting the switchgrass in August resulted in changes in vegetation structure and bird species composition the following nesting season. In harvested transects, residual vegetation was shorter and the litter layer was reduced in the year following harvest. Grassland bird species that preferred vegetation of short to moderate height and low to moderate density were found in harvested areas. Unharvested areas provided tall, dense vegetation structure that was especially attractive to tall-grass bird species, such as sedge wren (Cistothorus platensis) and Henslow's sparrow (Ammodramus henslowii). When considering wildlife habitat value in harvest management of switchgrass for biofuel, leaving some fields unharvested each year would be a good compromise, providing some habitat for a larger number of grassland bird species of management concern than if all fields were harvested annually. In areas where most idle grassland habitat present on the landscape is tallgrass, harvest of switchgrass for biofuel has the potential to increase the local diversity of grassland birds.

Ryu, C., Y. B. Yang, et al. (2006). "Effect of fuel properties on biomass combustion: Part I. Experiments - Fuel type, equivalence ratio and particle size." Fuel 85(7-8): 1039-1046.

Moving bed combustion is commonly used for energy conversion of biomass. Conditions on the moving bed can be conveniently represented by a time dependent fixed bed. The present work experimentally investigates the combustion of four biomass materials having different fuel properties in a fixed bed under fuel-rich conditions. Temperature, gas composition and mass loss curves identified two distinct periods as the combustion progresses in the bed: the ignition propagation and char oxidation. The effects of bulk density, particle size and air flow rate on the combustion characteristics during the two periods are interpreted by using the ignition front speed, burning rate, percentage of mass loss, equivalence ratio and temperature gradient. Different channelling of air was observed for small miscanthus pellets and large wood particles due to the fast propagation of the ignition front around a channel. The elemental ash composition was also analysed, which explained the sintered agglomerates of miscanthus ashes in terms of alkali index. copy 2005 Elsevier Ltd. All rights reserved.

Sengul, M. (2006). CO2 sequestration - A safe transition technology. 8th SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production 2006 8th SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production 2006.

Fossil fuel fired plants are responsible for the one third of the carbon dioxide (CO2) emissions which thought to be a major contributor to the current rise in the Earth's surface temperature. Reducing CO2 atmospheric concentrations by capturing emissions at the source - power plants or chemical units - and then storing them in subsurface reservoirs is thought by many scientists to be a reliable solution until emission-free energy sources are developed and viable. The current options for captured CO2 utilization are; Enhanced Oil Recovery (EOR), Enhanced Coal Bed Methane Recovery (ECBM), Enhanced Gas Recovery (EGR), Food processing applications, Mineral products, Fertilizer manufacture, Algae growth promoter, Enhanced plant growth. The capture and storage of CO2 continues to accelerate as new projects are initiated and existing projects confirm the development scenarios. A crucial element in CO2 storage is reliable monitoring of CO 2 migration behavior and storage volumes. An innovative seismic monitoring techniques, has recently been awarded a U.S. Department of Energy (DOE) project that will examine the application of timelapse (4D) seismic technology and advanced reservoir simulation to optimize CO2 EOR operations. Well design, cementing, completions techniques and long life cycle mechanical integrity assurance are currently subject of many R&D projects. Industry expertise also is being tapped in CO2 projects across Europe and in Australia, including four major EU proposals under the Framework Program Six and the Australian CO2CRC Orway Project. These projects address pertinent issues in CO2 capture and storage such as site selection, storage monitoring and verification techniques, developing local CO2 storage sites from hydrogen- and power-generation plants, and industry training. In our paper framework of CO2 sequestration and vital aspects such as; site selection, reservoir characterization, modeling of storage and long term leakage monitoring techniques will be illustrated.

Copyright 2006. Society of Petroleum Engineers.

Combustion – Fluidized Bed Boiler
Yantovski, E. I. (2008). "Solar energy conversion through seaweed photosynthesis and zero emissions power generation." Surface Engineering & Applied Electrochemistry 44(2): 138-145.
The present paper is aimed at describing a "closed cycle" power plant scheme (Solar Oxygen Fuel Turbine (SOFT)) with macroalgae (seaweed) cultivation in a pond, combustion of its organic matter in a fluidized bed boiler using the Rankine cycle, and return of the combustion products to the pond to feed the algae. The oxygen used for combustion is released to the atmosphere during

photosynthesis. It is further elaborated in a paper presented at ECOS2005 in Trondheim. As a renewable fuel, the seaweed Ulva lactuca is selected. Its growth rate in many experiments (in the literature) is 0.1-0.2 per day, the heating value of its dry weight is 19 MJ/kg, and its optimal concentration in salt water is 1:1000. The energy efficiency is less than in photovoltaics, but the energy expenditures to construct the pond as a solar energy receiver are much less, so it gives some economic benefits. For a power unit of 100 kW, the pond surface is about 4 hectare. The cultivation of seaweed in sea-water ponds is well developed in Italy and Israel for water cleaning and chemical production. Construction in the future of a SOFT system near the Dead Sea in the Israeli desert would provide the country with needed power, chemicals, and fresh water using solar energy. The system is protected by United States Patten no. 6 477 841 B1 dated 12.11.2002 with priority in Israel dated 22.03.1999. Many more benefits to the customer than are in the patent text are highlighted in the paper, including fresh water by desalination. In view of the active work in Italy on water cleaning using Ulva and contaminants in the water as nutrients for an increase of the biomass productivity, an additional target of the SOFT cycle might be incineration. Some suppositions of the use of a desert surface for massive scale use of ponds are given. copy Allerton Press, Inc. 2008.

Directly Burnable
Yantovski, E. I. (2008). "Solar energy conversion through seaweed photosynthesis and zero emissions power generation." Surface Engineering & Applied Electrochemistry 44(2): 138-145.
The present paper is aimed at describing a "closed cycle" power plant scheme (Solar Oxygen Fuel Turbine (SOFT)) with macroalgae (seaweed) cultivation in a pond, combustion of its organic matter in a fluidized bed boiler using the Rankine cycle, and return of the combustion products to the pond to feed the algae. The oxygen used for combustion is released to the atmosphere during photosynthesis. It is further elaborated in a paper presented at ECOS2005 in Trondheim. As a renewable fuel, the seaweed Ulva lactuca is selected. Its growth rate in many experiments (in the literature) is 0.1-0.2 per day, the heating value of its dry weight is 19 MJ/kg, and its optimal concentration in salt water is 1:1000. The energy efficiency is less than in photovoltaics, but the energy expenditures to construct the pond as a solar energy receiver are much less, so it gives some economic benefits. For a power unit of 100 kW, the pond surface is about 4 hectare. The cultivation of

seaweed in sea-water ponds is well developed in Italy and Israel for water cleaning and chemical production. Construction in the future of a SOFT system near the Dead Sea in the Israeli desert would provide the country with needed power, chemicals, and fresh water using solar energy. The system is protected by United States Patten no. 6 477 841 B1 dated 12.11.2002 with priority in Israel dated 22.03.1999. Many more benefits to the customer than are in the patent text are highlighted in the paper, including fresh water by desalination. In view of the active work in Italy on water cleaning using Ulva and contaminants in the water as nutrients for an increase of the biomass productivity, an additional target of the SOFT cycle might be incineration. Some suppositions of the use of a desert surface for massive scale use of ponds are given. copy Allerton Press, Inc. 2008.

Enzymatic Hydrolysis Keshwani, D. R., J. J. Cheng, et al. Microwave pretreatment of switchgrass to enhance enzymatic hydrolysis. 2007 ASABE Annual International Meeting, Technical Papers 2007 ASABE Annual International Meeting, Technical Papers. v 15 BOOK 2007. 8p 077127.
Switchgrass is a promising lignocellulosic biomass for fuel-ethanol production. However, pretreatment of lignocellulosic materials is necessary to improve its susceptibility to enzymatic hydrolysis. The objectives of this study were to examine the feasibility of microwave pretreatment to enhance enzymatic hydrolysis of switchgrass and to determine the optimal pretreatment conditions. Switchgrass samples immersed in water, dilute sulfuric acid and dilute sodium hydroxide solutions were exposed to microwave radiation at varying levels of radiation power and residence time. Pretreated solids were enzymatically hydrolyzed and reducing sugars in the hydrolysate were analyzed. Microwave radiation of switchgrass at lower power levels resulted in more efficient enzymatic hydrolysis. The application of microwave radiation for 10 minutes at 250 watts to switchgrass immersed in 3% sodium hydroxide solution (w/v) produced the highest yields of reducing sugar. Results were comparable to conventional 60 minute sodium hydroxide pretreatment of switchgrass. The findings suggest that combined microwave-alkali is a promising pre-treatment method to enhance enzymatic hydrolysis of switchgrass.

Fermentation Murnen, H. K., V. Balan, et al. (2007). "Optimization of Ammonia Fiber Expansion (AFEX) pretreatment and enzymatic hydrolysis of Miscanthus x giganteus to fermentable sugars." Biotechnology Progress 23(4): 846-850.
Miscanthus x giganteus is a tall perennial grass whose suitability as an energy crop is presently being appraised. There is very little information on the effect of pretreatment and enzymatic saccharification of Miscanthus to produce fermentable sugars. This paper reports sugar yields during enzymatic hydrolysis from ammonia fiber expansion (AFEX) pretreated Miscanthus. Pretreatment conditions including temperature, moisture, ammonia loading, residence time, and enzyme loadings are varied to maximize hydrolysis yields. In addition, further treatments such as soaking the biomass prior to AFEX as well as washing the pretreated material were also attempted to improve sugar yields. The optimal AFEX conditions determined were 160 degree C, 2:1 (w/w) ammonia to biomass loading, 233% moisture (dry weight

basis), and 5 min reaction time for watersoaked Miscanthus. Approximately 96% glucan and 81% xylan conversions were achieved after 168 h enzymatic hydrolysis at 1% glucan loading using 15 FPU/(g of glucan) of cellulase and 64 p-NPGU/(g of glucan) of beta-glucosidase along with xylanase and tween-80 supplementation. A mass balance for the AFEX pretreatment and enzymatic hydrolysis process is presented. copy 2007 American Chemical Society and American Institute of Chemical Engineers.

Fermentation – ASPEN Plus Model Wu, M., Y. Wu, et al. (2006). "Energy and emission benefits of alternative transportation liquid fuels derived from switchgrass: A fuel life cycle assessment." Biotechnology Progress 22(4): 1012-1024.
We conducted a mobility chains, or well-to-wheels (WTW), analysis to assess the energy and emission benefits of cellulosic biomass for the U.S. transportation sector in the years 2015-2030. We estimated the life-cycle energy consumption and emissions associated with biofuel production and use in light-duty vehicle (LDV) technologies by using the Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model. Analysis of biofuel production was based on ASPEN Plus model simulation of an advanced fermentation process to produce fuel ethanol/protein, a thermochemical process to produce Fischer-Tropsch diesel (FTD) and dimethyl ether (DME), and a combined heat and power plant to co-produce steam and electricity. Our study revealed that cellulosic biofuels as E85 (mixture of 85% ethanol and 15% gasoline by volume), FTD, and DME offer substantial savings in petroleum (66-93%) and fossil energy (65-88%) consumption on a per-mile basis. Decreased fossil fuel use translates to 82-87% reductions in greenhouse gas emissions across all unblended cellulosic biofuels. In urban areas, our study shows net reductions for almost all criteria pollutants, with the exception of carbon monoxide (unchanged), for each of the biofuel production option examined. Conventional and hybrid electric vehicles, when fueled with E85, could reduce total sulfur oxide (SO x)emissions to 39-43% of those generated by vehicles fueled with gasoline. By using bio-FTD and bio-DME in place of diesel, SOx emissions are reduced to 46-58% of those generated by diesel-fueled vehicles. Six different fuel production options were compared. This study strongly suggests that integrated heat and power co-generation by means of gas turbine combined cycle is a crucial factor in the energy savings and emission reductions. copy 2006 American Chemical Society and American Institute of Chemical Engineers.

Gassification Adler, P. R., M. A. Sanderson, et al. (2006). "Biomass yield and biofuel quality of switchgrass harvested in fall or spring." Agronomy Journal 98(6): 1518-1525.
Seasonal time of switchgrass (Panicum virgatum L.) harvest affects yield and biofuel quality and balancing these two components may vary depending on conversion system. A field study compared fall and spring harvest measuring biomass yield, element concentration, carbohydrate characterization, and total synthetic gas production as indicators of biofuel quality for direct combustion,

ethanol production, and gasification systems for generation of energy. Switchgrass yields decreased almost 40% (from about 7-4.4 Mg ha-1) in winters with above average snowfall when harvest was delayed over winter until spring. The moisture concentration also decreased (from about 350-70 g kg -1) only reaching low enough levels for safe storage by spring. About 10% of the yield reduction during winter resulted from decreases in tiller mass; however, almost 90% of the yield reduction was due to an increase in biomass left behind by the baler. Mineral element concentrations generally decreased with the delay in harvest until spring. Energy yield from gasification did not decrease on a unit biomass basis, whereas ethanol production was variable depending on the assessment method. When expressed on a unit area basis, energy yield decreased. Biofuel conversion systems may determine harvest timing. For direct combustion, the reduced mineral concentrations in spring-harvested biomass are desirable. For ethanol fermentation and gasification systems, however, lignocellulose yield may be more important. On conservations lands, the wildlife cover provided by switchgrass over the winter may increase the desirability of spring harvest along with the higher biofuel quality. copy American Society of Agronomy.

Hemicellulose Hydrolysis Jensen, J., J. Morinelly, et al. (2008). "Kinetic characterization of biomass dilute sulphuric acid hydrolysis: Mixtures of hardwoods, softwood, and switchgrass." AICHE Journal 54(6): 1637-1645.
The effects of woody biomass mixtures were investigated on the rates of hemicellulose hydrolysis by dilute acid. Very good agreement between the model predictions and single species acid hydrolysis data confirmed the validity of a pseudo first-order model approach. This model was then utilized to predict monomer sugar concentrations for mixtures of hardwood (aspen, basswood, and red maple), a softwood (balsam), and the energy crop switchgrass, with very good agreement. The results of this study show that there are not significant synergistic or antagonistic effects by mixtures of woody biomass species on the kinetics of hemicellulose hydrolysis by dilute acid. Kinetic parameters were developed for each woody biomass species with xylose formation activation energies ranging from 76.19-171.20 kJ/mol, and pre-exponential factors ranging from 2.19 multiplied by 108-7.73 multiplied by 1019 min-1. Overall xylose yields for pure biomass species ranged from approximately 66-88% with balsam having the lowest yield and switchgrass producing the highest yield. copy 2008 American Institute of Chemical Engineers.

Hydrocracking – [VGO] Bezergianni, S., A. Kalogianni, et al. (2009). "Hydrocracking of vacuum gas oilvegetable oil mixtures for biofuels production." Bioresource Technology 100(12): 3036- 3042.
Hydrocracking of vacuum gas oil (VGO) - vegetable oil mixtures is a prominent process for the production of biofuels. In this work both pre-hydrotreated and non-hydrotreated VGO are assessed whether they are suitable fossil components in a VGO-vegetable oil mixture as feed-stocks to a hydrocracking process. This assessment indicates the necessity of a VGO pre-hydrotreated step prior to hydrocracking the VGO-vegetable oil mixture. Moreover, the comparison of two different mixing ratios suggests that higher vegetable oil content favors hydrocracking product yields and qualities. Three commercial catalysts of different activity are utilized in order to identify a range of products that can be produced via a

hydrocracking route. Finally, the effect of temperature on hydrocracking VGO-vegetable oil mixtures is studied in terms of conversion and selectivity to diesel, jet/kerosene and naphtha.

Hydrogen Production – Sulfur Deprived Algal Cultures Jorquera, O., A. Kiperstok, et al. (2008). "S-systems sensitivity analysis of the factors that may influence hydrogen production by sulfur-deprived Chlamydomonas reinhardtii." International Journal of Hydrogen Energy 33(9): 2167-2177.

We built a metabolic map of the hydrogen production process by the microalga Chlamydomonas reinhardtii, mathematically modeled this map in the S-systems formalism, then analyzed the effect of variations in the value of different model parameters on the overall response of the system. The mathematical model exhibited behavior similar to that described in literature for photosynthetic algal hydrogen production by sulfur-deprived algal cultures. This behavior consists of an initial phase during which oxygen is transiently generated and then consumed, followed by an anaerobic phase that is characterized by generation of hydrogen. Our analysis of the effect of independent variables on the hydrogen production process mostly agrees with previous work left bracket Horner J, Wolinsky M. A power-law sensitivity analysis of the hydrogen-producing metabolic pathway in Chlamydomonas reinhardtii. Int J Hydrogen Energy 2002;27: 1251-1255 right bracket . Moreover, a more detailed study of the effects of parameter modification (rate constants and kinetic order) indicated that genetic engineering of the hydrogenase expression, activity and stability may lead to increased performance of the process.

Hydrothermolysis Suryawati, L., M. R. Wilkins, et al. Effect of hydrothermolysis on ethanol yield from Alamo switchgrass using a thermotolerant yeast. 2007 ASABE Annual International Meeting, Technical Papers 2007 ASABE Annual International Meeting, Technical Papers. v 15 BOOK 2007. 13p 077071.

Switchgrass is a perennial grass that has potential as a feedstock for ethanol production. Using switchgrass for ethanol production would reduce dependence on food crops, such as corn, that are currently used for fuel ethanol. Hot compressed liquid water was used to treat Alamo switchgrass in a method called hydrothermolysis to disrupt lignin, dissolve hemicellulose, and increase accessibility of cellulose to hydrolysis enzymes. Hydrothermolysis was selected instead of other common methods to minimize formation of inhibitors, chemical use, and corrosion of process equipment. Three temperatures (190, 200, and 210 degree C) and hold times (10, 15, and 20 min) were used to pretreat Alamo switchgrass at 10% solids to prepare it for SSF (Simultaneous saccharification and fermentation). Prehydrolyzate from switchgrass treated at 190 degree C for 10 min had the greatest xylan recovery in the hydrolyzate. From all treatment conditions, less than 0.65 g/L glucose were released into the prehydrolyzate, indicating most glucose was retained as cellulose in the solid substrate. HMF (5-hydroxymethylfurfural) and furfural formation in the prehydrolyzate were found to be less than 1 g/L for all treatments. The highest theoretical yield of ethanol (82%, 18.6 g/L) was produced from switchgrass pretreated at 200 degree C and 10 min using SSF at 45 degree C with thermotolerant yeast Kluyveromyces marxianus IMB 4 and 15 FPU cellulase/g glucan loading. The glucan loading for SSF was 40 g/L.

Hydrogenase Carrieri, D., G. Ananyev, et al. (2008). "Renewable hydrogen production by cyanobacteria: Nickel requirements for optimal hydrogenase activity." International Journal of Hydrogen Energy 33(8): 2014-2022.

Some species of cyanobacteria naturally produce hydrogen gas as a byproduct of anaerobic fermentation at night using fixed-carbon compounds that are produced photosynthetically in daylight under aerobic conditions. The nutrient requirements for optimal activity of these two systems of metabolic energy production are different and in some cases incompatible. Resolving these conflicting needs has not been widely considered, yet is critical for application of cyanobacteria as efficient cell factories for hydrogen production. The filamentous nondiazotrophic cyanobacterium Arthrospira maxima ferments in the dark both intracellular fixed-carbon compounds and added glucose, producing hydrogen exclusively via a bidirectional NiFe hydrogenase. We show that the hydrogenase activity in cell extracts (in vitro) and whole cells (in vivo) correlates with the amount of Ni2 + in the growth medium (saturating activity at 1.5 mu MNi2 +). This and higher levels of nickel in the medium during photoautotrophic growth cause stress leading to chlorophyll degradation and a retarded growth rate that is severe at ambient solar flux. We show that A. maxima acclimates to micromolar nickel concentrations at reduced light intensity after a delay which minimizes chlorophyll degradation and restores normal growth rate. Nickel adaptation permits normal biomass accumulation while significantly increasing the rate of fermentative hydrogen production. Relative to nickel-free media (only extraneous Ni2 +), the average hydrogenase activity in cell extracts (in vitro) increases by 18-fold, while the average rate of intracellular H2 production within intact cells increases 6-fold. Nickel is inferred to be a limiting cofactor for hydrogenase activity in many cyanobacteria grown using photoautotrophic conditions, particularly those lacking a high-affinity Ni2 + transport system. copy 2008 International Association for Hydrogen Energy.

Laboratory Fire Suspension Testing Capablo, J. n., P. A. Jensen, et al. "Ash Properties of Alternative Biomass." Energy & Fuels 0(0).

The ash behavior during suspension firing of 12 alternative solid biofuels, such as pectin waste, mash from a beer brewery, or waste from cigarette production have been studied and compared to wood and straw ash behavior. Laboratory suspension firing tests were performed on an entrained flow reactor and a swirl burner test rig, with special emphasis on the formation of fly ash and ash deposit. Thermodynamic equilibrium calculations were performed to support the interpretation of the experiments. To generalize the results of the combustion tests, the fuels are classified according to fuel ash analysis into three main groups depending upon their ash content of silica, alkali metal, and calcium and magnesium. To further detail the biomass classification, the relative molar ratio of Cl, S, and P to alkali were included. The study has led to knowledge on biomass fuel ash composition influence on ash transformation, ash deposit flux, and deposit chlorine content when biomass fuels are applied for suspension combustion.

Linear Knife Grid Device for Biomass Igathinathane, C., A. R. Womac, et al. Size reduction of wet and dry biomass by linear knife grid device. 2007 ASABE Annual International Meeting, Technical Papers 2007 ASABE Annual International Meeting, Technical Papers. v 11 BOOK 2007. 15p 076045.

Linear action of forcing biomass materials through a grid of interlocking knives is an alternative method of size reduction, contrast to rotary action involved in existing size reduction machines. A laboratory-scale linear action knife grid device prototype developed earlier was used to determine the size reduction characteristics of selected biomass, namely, corn stalks and switchgrass at several material and operating conditions. This study was aimed at determining and comparing the ultimate cutting stresses and cutting energy variation between corn stalks and switchgrass, moisture conditions (high- and low-moisture), knife grid spacing (25.4, 50.8, and 101.6 mm), and packed bed depth (50.8, 101.6, and 152.4 mm). The device is composed of ram- attached to crosshead of universal testing machine (UTM), feed block - holds feed, knife grid - arranged at variable grid spacing, knife holder block - holds knife grid, and product block - collects product, and the whole assembly is tested in UTM fitted with 222.41 kN (5000 lb) load cell. New surface area generated during size reduction was evaluated based on circle packing theory. Ultimate cutting stresses were evaluated as the ratio of peak load to the cutting plane area (MPa) represented by the knife grid. Cutting energies were evaluated from the area under loaddisplacement curves and expressed in moisture free basis mass-based energy (MJ/dry Mg) and new surface area-based energy (kJ/m 2). Overall results indicated that ultimate cutting stress and cutting energy of com stalks were significantly (P less than 0.05) greater (2.2 times) than that of switchgrass. Highmoisture material required significantly greater stress and energy (1.3 times) than low-moisture material. Grid spacing produced significant difference in cutting energy but not with ultimate cutting stress. Energy values required in size reduction using linear knife grid device was much smaller than that reported for similar biomass using other methods of size reduction. Therefore, a preprocessing machine, based on linear knife grid principle, with 50 to 100 mm and greater grid spacing would be an efficient first stage size reduction for biomass materials.

Igathinathane, C., A. R. Womac, et al. (2008). "Knife grid size reduction to pre-process packed beds of high- and low-moisture switchgrass." Bioresource Technology 99(7): 2254-2264.

A linear knife grid device was developed for first-stage size reduction of high- and low-moisture switchgrass (Panicum virgatum L.), a tough, fibrous perennial grass being considered as a feedstock for bioenergy. The size reduction is by a shearing action accomplished by forcing a thick packed bed of biomass against a grid of sharp knives. The system is used commercially for slicing forages for drying or feed mixing. No performance data or engineering equations are available in published literature to optimize the machine and the process for biomass size reductions. Tests of a linear knife grid with switchgrass quantified the combined effect of shearing stresses, packed bed consolidation, and frictional resistance to flow through a knife grid. A universal test machine (UTM) measured load-displacement of switchgrass at two moisture contents: 51%, and 9% wet basis; three knife grid spacings: 25.4, 50.8, and 101.6 mm; and three packed bed depths: 50.8, 101.6, and 152.4 mm. Results showed that peak load, ultimate shear stress, and cutting energy values varied inversely with knife grid spacing and directly with packed bed depth (except ultimate shear stress). Mean ultimate shear stresses of high- and low-moisture switchgrass were 0.68 plus or minus 0.24, and 0.41 plus or minus 0.21 MPa, mass-based cutting energy values were 4.50 plus or minus 4.43, and 3.64 plus or minus 3.31 MJ/dry Mg, and cutting energy based on new surface area, calculated from packed-circle theory, were 4.12 plus or minus 2.06, and 2.53 plus or minus 0.45 kJ/m2, respectively. The differences between high- and low-moisture switchgrass were significant (P less than 0.05), such that high-moisture switchgrass required increased shear stress and cutting energy. Reduced knife grid spacing and increased packed bed depths required increased cutting energy. Overall, knife grid cutting energy was much less than energy values published for rotary equipment. A minimum knife grid spacing of 25.4 mm appears to be a practical lower limit, considering the high ram force that would be needed for commercial operation. However, knife grid spacing from 50 to 100 mm and greater may offer an efficient first-stage size reduction, especially well suited for packaged (baled) biomass. Results of this research should aid the engineering design of size reduction equipment for commercial facilities. copy 2007.

Microwave Boldor, D., S. Balasubramanian, et al. (2008). "Design and implementation of a continuous microwave heating system for ballast water treatment." Environmental Science & Technology 42(11): 4121-4127.
A continuous microwave system to treat ballast water inoculated with different invasive species was designed and installed at the Louisiana State University Agricultural Center. The effectiveness of the system to deliver the required heating loads to inactivate the organisms present was studied. The targeted organisms were microalgae (Nannochloropsis oculata), zooplankton at two different growth stages (newly hatched brine shrimp-Artemia nauplii and adult Artemia), and oyster larvae (Crassosstrea virginica). The system was tested at two different flow rates (1 and 2 liters per min) and power levels (2.5 and 4.5 kW). Temperature profiles indicate that, depending on the species present and the growth stage, the maximum temperature increase will vary from 11.8 to 64.9 degree C. The continuous microwave heating system delivered uniform and near-instantaneous heating at the outlet, proving its effectiveness. The power absorbed and power efficiency varied for the species present. More than 80% power utilization efficiency was obtained at all flow rate and microwave power combinations for microalgae, Artemia nauplii and adults. Test results indicated that microwave treatment can be an effective tool for ballast water treatment, and current high treatment costs notwithstanding, this technique can be added as supplemental technology to the palette of existing treatment methods. copy 2008 American Chemical Society.

Hu, Z., Y. Wang, et al. (2008). "Alkali (NaOH) pretreatment of switchgrass by radio frequency-based dielectric heating." Applied Biochemistry & Biotechnology 148(1-3): 71-81.

Radio-frequency (RF)-based dielectric heating was used in the alkali (NaOH) pretreatment of switchgrass to enhance its enzymatic digestibility. Due to the unique features of RF heating (i.e., volumetric heat transfer, deep heat penetration of the samples, etc.), switchgrass could be treated on a large scale, high solid content, and uniform temperature profile. At 20% solid content, RFassisted alkali pretreatment (at 0.1 g NaOH/g biomass loading and 90 degree C) resulted in a higher xylose yield than the conventional heating pretreatment. The enzymatic hydrolysis of RF-treated solids led to a higher glucose yield than the corresponding value obtained from conventional heating treatment. When the solid content exceeded 25%, conventional heating could not handle this highsolid sample due to the loss of fluidity, poor mixing, and heating transfer of the samples. As a result, there was a significantly lower sugar yield, but the sugar yield of the RF-based pretreatment process was still maintained at high levels. Furthermore, the optimal particle size and alkali loading in the RF pre-treatment was determined as 0.25-0.50 mm and 0.25 g NaOH/g biomass, respectively. At alkali loading of 0.20-0.25 g NaOH/g biomass, heating temperature of 90oC, and solid content of 20%, the glucose, xylose, and total sugar yield from the combined RF pretreatment and the enzymatic hydrolysis were 25.3, 21.2, and 46.5 g/g biomass, respectively. copy 2007 Humana Press Inc.

Nanobiocatalysis Kim, J., J. W. Grate, et al. (2008). "Nanobiocatalysis and its potential applications." Trends in Biotechnology 26(11): 639-646.

Nanobiocatalysis, in which enzymes are incorporated into nanostructured materials, has emerged as a rapidly growing area. Nanostructures, including nanoporous media, nanofibers, carbon nanotubes and nanoparticles, have manifested great efficiency in the manipulation of the nanoscale environment of the enzyme and thus promise exciting advances in many areas of enzyme technology. This review will describe these recent developments in nanobiocatalysis and their potential applications in various fields, such as trypsin digestion in proteomic analysis, antifouling, and biofuel cells.

Photo-bioreactor Ai, W., S. Guo, et al. (2008). "Development of a ground-based space micro-algae photobioreactor." Advances in Space Research 41(5): 742-747.

The purpose of the research is to develop a photo-bioreactor which may produce algae protein and oxygen for future astronauts in comparatively long-term exploration, and remove carbon dioxide in a controlled ecological life support system. Based on technical parameters and performance requirements, the project planning, design drafting, and manufacture were conducted. Finally, a demonstration test for producing algae was done. Its productivity for micro-algae and performance of the photo-bioreactor were evaluated. The facility has nine subsystems, including the reactor, the illuminating unit, the carbon dioxide (CO2) production unit and oxygen (O2) generation unit, etc. The demonstration results showed that the facility worked well, and the parameters, such as energy consumption, volume, and productivity for algae, met with the design requirement. The density of algae in the photo-bioreactor increased from 0.174 g (dry weight) L-1 to 4.064 g (dry weight) L-1 after 7 days growth. The principle of providing CO2 in the photo-bioreactor for algae and removing O2 from the culture medium was suitable for the demand of space conditions. The facility has reasonable technical indices, and smooth and dependable performances. Copy 2007 COSPAR.

Meireles, L. A., A. C. Guedes, et al. (2008). "On-line control of light intensity in a microalgal bioreactor using a novel automatic system." Enzyme & Microbial Technology 42(7): 554-559.
The influence of light intensity upon biomass and fatty acid productivity by the microalga Pavlova lutheri was experimentally studied using a novel device. This device was designed to automatically adjust light intensity in a photobioreactor: it takes on-line measurements of biomass concentration, and was successfully tested to implement a feedback control of light based on the growth rate variation. Using said device, batch and semicontinuous cultures of P. lutheri were maintained at maximum growth rates and biomass productivities – hence avoiding photoinhibition, and consequent waste of radiant energy. Several cultures were run with said device, and their performances were compared with those of control cultures submitted to constant light intensity; the biomass levels attained, as well as the yields of eicosapentaenoic and docosahexaenoic acids were calculated - and were consistently higher than those of their uncontrolled counterpart. copy 2008 Elsevier Inc. All rights reserved.

Panti, L., P. Chavez, et al. A solar photobioreactor for the production of biohydrogen from microalgae. Proceedings of SPIE - The International Society for Optical Engineering Solar Hydrogen and Nanotechnology II. v 6650 2007.
The green microalga Chlamydomonas reinhardtii is proposed to produce hydrogen in a low-cost system using the solar radiation in Yucatan, Mexico. A two-step process is necessary with a closed photobioreactor, in which the algae are firstly growth and then induced for hydrogen generation. Preliminary results are presented in this work with some planning for the future. Different culture broths, temperatures and light intensities were tested for biomass and hydrogen production in laboratory conditions. The first experiments in external conditions with solar radiation and without temperature control have been performed, showing the potential of this technique at larger scales. However, some additional work must be done in order to optimize the culture maintenance, particularly in relation with the temperature control, the light radiation and the carbon dioxide supply, with the idea of keeping an economic production.

Skjanes, K., G. Knutsen, et al. (2008). "H2 production from marine and freshwater species of green algae during sulfur deprivation and considerations for bioreactor design." International Journal of Hydrogen Energy 33(2): 511-521.
Twenty-one species of green algae isolated from marine, freshwater and terrestrial environments were screened for the ability to produce H2 under anaerobic conditions. Seven strains found positive for H2 production under anaerobic conditions were also screened for the ability to produce H2 under sulfur (S)

deprivation. In addition to the traditional model species Chlamydomonas reinhardtii, C. noctigama (freshwater) and C. euryale (brackish water) were able to produce significant amounts of H2 under S-deprivation. These species were also able to utilize acetate as a substrate for growth in light. The S-deprivation experiments were performed under photoheterotrophic conditions in a purpose-specific designed bioreactor, and it was shown that an automated pH adjustment feature was essential to maintain a stable pH in the cultures. Several materials commonly used in bioreactors, such as rubber materials, plastics and steel alloys, had a negative effect on the survival of S deprived algae cultures. Unexpectedly, traces of H2 were produced under Sdeprivation during O2 saturation in the cultures, possibly derived from local anaerobic environments formed in algal biofilms on the membranes covering the O2 electrodes. copy 2007 International Association for Hydrogen Energy.

Zemke, P. E., B. D. Wood, et al. (2007). Economic analysis of a vertical sheet algal photobioreactor for biodiesel production. Proceedings of the Energy Sustainability Conference 2007 Proceedings of the Energy Sustainability Conference 2007.
The combination of a 100% increase in diesel fuel prices since 2002 and a new photobioreactor technology has renewed interest in producing biodiesel, a direct petroleum diesel fuel substitute, from microalgae. A new photobioreactor technology in which the microalgae are grown on vertically suspended membranes promises to increase algal productivity per acre ten-fold compared to microalgae ponds, and 400-fold compared to soybeans. This paper describes the general photobioreactor concept and assesses the economic viability of such technology given the current crude oil prospects. The majority of the data necessary for assessment are obtained from published articles, with experimental results providing the remaining necessary information. Analysis results indicate that the photobioreactor would need to be constructed and operate on the order of dollars per square foot per year. Copyright copy 2007 by ASME.

Photovoltaic Cells Gust, D., D. Kramer, et al. (2008). "Engineered and artificial photosynthesis: Human ingenuity enters the game." MRS Bulletin 33(4): 383-387.
The process of engineered and artificial photosynthesis activities are increasingly influenced by human related factors. Humans have created direct ways for harnessing solar energy, such as photovoltaic (PV) cells, which produce energy in the form of electromotive force (emf, electricity). They are making transformation progress with an aim to supplant fossil fuels to offer energy security and reduction in climate change can be performed at the intersection of technology and biology. Energy conversion efficiency (ECE), which is a fundamental parameter to determine the area needed to offer a specified amount of energy for human use, should be calculated using insolation (incident solar energy) per year summed over diurnal and seasonal cycles. Some algae and cyanobacteria, which possess significantly higher ECEs than terrestrial plants, can also be used to achieve far better ECE by clustering them for biofuel production than by growing terrestrial plants.

Sorption of Hexalent Chromium Basha, S., Z. V. P. Murthy, et al. (2008). "Biosorption of

hexavalent chromium by chemically modified seaweed, Cystoseira indica." Chemical Engineering Journal 137(3): 480-488.

The sorption of hexavalent chromium by marine brown algae Cystoseira indica, which was chemically-modified by cross-linking with epichlorohydrin (CB1, CB2), or oxidized by potassium permanganate (CB3), or only washed by distilled water (RB) was studied with variation in the parameters of contact time, pH, initial metal ion concentration and solid/liquid ratio. They were used for equilibrium sorption uptake studies with Cr(VI). The results indicate that biosorption equilibriums were rapidly established in about 2 h. The Cr(VI) adsorption was strictly pH dependent, and maximum removal of Cr(VI) on biosorbents were observed at pH 3.0. The maximum Chromium uptakes were 22.7, 24.2, 20.1 and 17.8 mg g-1, respectively, for CB1, CB2, CB3 and RB. The order of maximum Cr(VI) uptakes for various biomasses was CB2 greater than CB1 greater than CB3 greater than RB. A comparison of different isotherm models revealed that the Dubinin- Radushkevich (D-R) isotherm model fitted the experimental data best based on R2, qmax and standard error (S.E.) values and the mean energy of the sorption values indicated that biosorption of Cr(VI) by C. indica may be an ion exchange reaction. copy 2007 Elsevier B.V. All rights reserved.

Thermochemical Balat, M. (2008). "Global trends on the processing of bio-fuels." International Journal of Green Energy 5(3): 212-238.

The aim of the present paper is to investigate bio-fuels produced from biomass materials by thermochemical and biochemical methods and the utilization trends of the products in the world. Bio-fuels are liquid or gaseous fuels made from plant matter and residues, such as agricultural crops, municipal wastes and agricultural and forestry by-products. Liquid bio-fuels being considered world over fall into the following categories: (a) vegetable oils and biodiesels; (b) alcohols; and (c) biocrude and synthetic oils. Bioethanol can be produced from cellulose feedstocks such as corn stalks, rice straw, sugar cane bagasse, pulpwood, switchgrass, and municipal solid waste. Conversion technologies for producing bioethanol from cellulosic biomass resources such as forest materials, agricultural residues and urban wastes are under development and have not yet been demonstrated commercially. Biodiesel fuel can be made from new or used vegetable oils and animal fats, which are non-toxic, biodegradable, renewable resources.The problems with substituting triglycerides for diesel fuels are mostly associated with their high viscosities, low volatilities and polyunsaturated character. Different ways have been considered to reduce the high viscosity of vegetable oils.

Khelfa, A., V. Sharypov, et al. (2009). "Catalytic pyrolysis and gasification of Miscanthus Giganteus: Haematite (Fe2O3) a versatile catalyst." Journal of Analytical and Applied Pyrolysis 84(1): 84-88.

The present work describes the catalytic steam gasification and pyrolysis of Miscanthus × Giganteus pellets. Alone or in combination, pyrolysis and gasification catalytic processes lead nowadays to promising methods for the production of energy and chemicals from various biomass. In our best conditions,

steam gasification at 850 °C in the presence of 3 wt.% h aematite, leads to 94.8 wt.% of gases

and 5.2 wt.% liquids in 20 min. The gases composition (vol%) was: H2--45.7, CO--34.1, CO2--14.7, CH4--4.2 and others--1.3. In the presence of steam, haematite an iron oxide used as catalyst is active in the gasification and hydrogen production, is able to breakdown the tar produced during the thermal degradation of the biomass and leads to the partial oxidation of phenols. The influence of catalyst in pyrolysis is limited and only a decrease in liquids yields is observed.

Ross, A. B., J. M. Jones, et al. (2008). "Classification of macroalgae as fuel and its thermochemical behaviour." Bioresource Technology 99(14): 6494-6504.

A preliminary classification of five macroalgae from the British Isles; Fucus vesiculosus, Chorda filum, Laminaria digitata, Fucus serratus, Laminaria hyperborea, and Macrocystis pyrifera from South America, has been presented in terms of a Van Krevelen diagram. The macroalgae have been characterised for proximate and ultimate analysis, inorganic content, and calorific value. The different options for thermal conversion and behaviour under combustion and pyrolysis have been evaluated and compared to several types of terrestrial biomass including Miscanthus, short rotation Willow coppice and Oat straw. Thermal treatment of the macroalgae has been investigated using thermogravimetry (TGA) and pyrolysis-gc-ms. Combustion behaviour is investigated using TGA in an oxidising atmosphere. The suitability of macroalgae for the different thermal processing routes is discussed. Ash chemistry restricts the use of macroalgae for direct combustion and gasification. Pyrolysis produces a range of pentosans and a significant proportion of nitrogen containing compounds. High char yields are produced.

Thermochemical – Pyrolysis Balat, M. (2008). "Mechanisms of thermochemical biomass conversion processes. Part 1: Reactions of pyrolysis." Energy Sources Part A-Recovery Utilization & Environmental Effects 30(7): 620-635.

The present work is a study on the pyrolysis mechanisms of biomass structural constituents. Biomass resources include wood and wood wastes, agricultural crops and their waste byproducts, municipal solid waste, animal wastes, waste from food processing, and aquatic plants and algae. The major organic components of biomass can be classified as cellulose, hemicelluloses, and lignin. The pyrolysis is thermal degradation of biomass by heat in the absence of oxygen, which results in the production of charcoal (solid), bio-oil (liquid), and fuel gas products. Thermal degradation of cellulose proceeds through two types of reaction: a gradual degradation, decomposition, and charring on heating at lower temperatures; and a rapid volatilization accompanied by the formation of levoglucosan on pyrolysis at higher temperatures. The hemicelluloses reacted more readily than cellulose during heating. Of the hemicelluloses, xylan is the least thermally stable, because pentosans are most susceptible to hydrolysis and dehydration reactions. Dehydration reactions around 473 K are primarily responsible for thermal degradation of lignin. Between 423 K and 573 K, cleavage of alpha- and -betaaryl-alkyl-ether linkages occurs. Around 573 K, aliphatic side chains start splitting off from the aromatic ring.

Boateng, A. A. (2005). Pyrolysis of alfalfa stems and dedicated herbaceous energy crops in the national biomass initiative program. 2005 AIChE Spring National Meeting, Conference Proceedings 2005 AIChE Spring National Meeting, Conference Proceedings.
In order to tackle the challenges of developing a biobased industry in the U.S., the 2000 biomass research and development act directs the US-DOE and USDA to integrate technology R&D programs through the Biomass Initiative. Current conversion technologies under the initiative are based on the sugar and the thermochemical platform technologies. Between these two platforms thermochemical conversion shows nearer-time promise towards developing integrated bio-refineries in the US. Pyrolysis is one process under this platform that has gained attention because it can be used to produce pyrolytic oil intermediates that can be subsequently refined to form valuable chemicals and energy carriers such as hydrogen. The role which the choice of biomass plays in achieving economic competitiveness compared with fossil fuel conversion is well documented and hence research emphasis has been placed on dedicated energy crops. In this submission, the results of the pyrolysis of alfalfa stems and certain herbaceous crops specifically, switchgrass and reed canary grass, which are identified under the biomass initiative program as dedicated energy crops, are presented. The pyrolysis was carried out in a PY-GC/MS system to determine the effect of temperature and crop maturity on gas yield. The results show distinct yield patterns and differences between the alfalfa and the herbaceous forages. The information is useful for the evaluation and comparison of the various conversion routes identified under the initiative.

Boateng, A. A. (2007). "Characterization and thermal conversion of charcoal derived from fluidized-bed fast pyrolysis oil production of switchgrass." Industrial & Engineering Chemistry Research 46(26): 8857-8862.
The charcoal coproduct associated with pyrolysis oil (bio-oil) production can add economic value to the process operation if it can be successfully employed as an activated biochar for soil amendment applications or can be used as a combustion fuel to power the pyrolysis process or as a gasifier feedstock. Although proposed, none of these have been extensively studied. In this submission, the surfaces and interfaces of the charcoal produced from making pyrolysis oil from switchgrass in a fluidized bed were characterized to establish its usefulness as an adsorbent material. Its reactivity in air and in CO2 were also determined to establish its potential as combustion fuel or gasification feedstock. It was found that the surface areas were low, typically 7.7 and 7.9 m2/g, 2 orders of magnitude of the areas encountered in activated charcoal. Compounding this was high surface crystallinity of the structure as measured by X-ray diffraction, thereby suggesting poor characteristics as a sorption agent without further activation. However, this does not preclude its use for other soil applications including carbon storage and as a nutrient delivery substrate. Upon further pyrolysis in helium, the charcoal yielded equal amounts of CO and CO2, exhibiting reaction kinetics similar to that of coal pyrolysis. Furthermore, reactivity in CO2 and in air atmosphere resulted in activation energies of 8 411 and 11 487 J/mol,

respectively. It appears that the charcoal could be better used as combustion fuel or gasification feedstock than as an activated charcoal applied for metal sorption for the fact that the latter application will require higher surface and interfacial areas than measured.

Boateng, A. A., K. B. Hicks, et al. (2006). "Pyrolysis of switchgrass (Panicum virgatum) harvested at several stages of maturity." Journal of Analytical & Applied Pyrolysis 75(2): 55-64.
The pyrolysis of switchgrass (Panicum virgatum) of the cultivar, "Cave-in-Rock" harvested at three stages of physiological maturity was studied in a PY-GC/MS system at the 600-1050 degree C temperature range. Under these conditions, the decomposition was complete within 20 s yielding char, and two sets of pyrolysis gas, condensable and non-condensable. The former consisted of acetaldehyde (CH3CHO), acetic acid (CH3COOH) and higher molecular weight compounds possibly from the hydroxyl group and from the methoxy groups of the cell wall components. The non-condensable gases were mainly CO, CO2 and C1-C3 hydrocarbons. For these, there was a 900 degree C temperature boundary where dramatic change occurred in their evolution rates. Below this temperature, CO2 decreased but CO and the C1-C3 hydrocarbons increased almost linearly with temperature. Above this temperature boundary, the hydrocarbons leveled off but there was a rapid rise in CO and CO2 evolution at a constant CO/CO2 ratio. These suggest the appearance of secondary or tertiary pyrolysis reactions involving rearrangement and release of CO and hydrocarbons prior to this temperature boundary and the release of CO and CO2 from the tightly bond oxygen functionalities including C-C bonds thereafter. At less than 750 degree C, there were modest increases in condensable gas yield and decrease in non-condensable gas due to differences in plant maturity at harvest. However, the effect of switchgrass physiological maturity on gas yield was statistically insignificant at high temperatures. The energy content of the noncondensable gas measured was about 68% of the gross energy content of the biomass for the early harvest crop and 80% for the mature crop. The activation energy for the decomposition, estimated assuming first order reaction kinetics, showed a linear increase with plant physiological maturity. The results demonstrate that physiological maturity at harvest of switchgrass biomass can result in different concentrations of pyrolysis products at different temperatures. These results also demonstrate the need for additional research with a broader array of herbaceous biomass materials to develop a better understanding of the synergies of crop cultivation, harvesting and processing of dedicated herbaceous biomass energy crops during their thermochemical conversion. copy 2005 Elsevier B.V. All rights reserved.

Ji, L., L.-X. Zhang, et al. (2007). "Review on the progress of producing bio-fuel from microalgae." Shiyou Xuebao, Shiyou Huagong/Acta Petrolei Sinica (Petroleum Processing Section) 23(6): 1-5.
The sustainable and steady development of bio-fuels, including biodiesel and bio-oils, must secure stable and high quality raw materials, while microalgae is one of them. In this paper, the concept of microalgae was introduced and the research and development about the production of biodiesel and bio-oils in the world

were reviewed. The emphasis was put on the progress on the synthesis of microalgae by genetic engineering, new reactor and coupling process, as well as the production of bio-oil from pyrolysis of microalgae and direct usage of microalgae as fuel. Finally, the advantages and problems in making bio-fuel from microalgae were discussed.

Tsamba, A. J., W. Yang, et al. (2007). "Cashew nut shells pyrolysis: Individual gas evolution rates and yields." Energy & Fuels 21(4): 2357-2362.
Cashew nut shells are one type of the most abundant biomass tropical wastes, which can be used for energy generation. However, there is lack of data for the thermal conversion process of cashew nut shells such as pyrolysis individual gas products, yields, and reaction kinetics. In this research work, the pyrolysis processes of cashew nut shells at low heating rates (10, 30, and 100 K/min) were studied. Thermogravimetric analyzer coupled with a Fourier transform infrared spectrometer (TG-FTIR) was used. The pyrolysis product yields obtained were compared with the available data in the literature for wood and Miscanthus Giganteus. It was found that cashew nut shells have tars and volatiles at levels equivalent to those of wood pellets, both above the tar and volatile content of M. Giganteus. Further, kinetic parameters were obtained from the TG-FTIR results using an approach based on parallel independent first-order reactions with a Gaussian distribution of activation energies and following the Tmax method. The data obtained through this approach included the identification, kinetics, and yield of each gas product precursor. These results are then used as input files for a distributed activation energy model (DAEM) for biomass pyrolysis, based on a functional group analysis, which still does not include the devolatilization, crosslinking competitive reactions. The predicted evaluation data from this model were found to generally agree with that from TG-FTIR analysis. However, the model still demands improvement to accommodate secondary and cross-linking competitive reactions. copy 2007 American Chemical Society.

Yorgun, S. and Y. E. Simsek (2008). "Catalytic pyrolysis of Miscanthus multiplied by giganteus over activated alumina." Bioresource Technology 99(17): 8095-8100.
The catalytic effects of activated alumina (Al_2O_3) on the pyrolysis of Miscanthus multiplied by giganteus, a new energy crop, were investigated. Catalytic pyrolysis experiments carried out under static and nitrogen atmospheres were performed in a fixed-bed reactor. The final pyrolysis temperature was kept constant at 550 degree C in all of the experiments. The effect of catalyst loading (by weight of feedstock as 10%, 20%, 40%, 60%, 80% and 100%), heating rate (10 degree C and 50 degree C min-1), nitrogen flow rate (50, 100, 150 and 200 cm3 min-1) on the pyrolysis conversion and product yields were investigated. The results were compared with those obtained in non-catalytic pyrolysis. Activated alumina catalyst has a strong influence on the Miscanthus multiplied by giganteus pyrolysis product and conversion yield. Furthermore, the catalytic bio-oils obtained from catalytic pyrolysis under static and nitrogen atmospheres were examined using elemental analysis, column chromatography, Fourier transform infrared (FTIR) and nuclear magnetic

resonance (1H NMR) spectroscopy methods.

Thermochemical – Pyrolysis – Fast Boateng, A. A., D. E. Daugaard, et al. (2007). "Bench-scale fluidized-bed pyrolysis of switchgrass for bio-oil production." Industrial & Engineering Chemistry Research 46(7): 1891-1897.

The U.S. biomass initiative is counting on lignocellulosic conversion to boost the quantities of biofuels currently produced from starches in order to achieve much needed energy security in the future. However, with current challenges in fermentation of lignocellulosic material to ethanol, other methods of converting biomass to usable energy have received consideration nationally. One thermochemical technique, fast pyrolysis, is being considered by the Agricultural Research Service (ARS) researchers of the USDA for processing energy crops such as switchgrass and other agricultural residues, e.g., barley hulls and alfalfa stems for bio-oil (pyrolysis oil or pyrolysis liquids) production. A 2.5 kg/h biomass fast pyrolyzer has been developed at ARS and tested for switchgrass conversion. The unit has provided useful data such as energy requirements and product yields that can be used as design parameters for larger systems based on the processing of perennial energy crops. Bio-oil yields greater than 60% by mass have been demonstrated for switchgrass, with energy conversion efficiencies ranging from 52 to 81%. The results show that char yielded would suffice in providing all the energy required for the endothermic pyrolysis reaction process. The composition of the noncondensable gas produced has been initially characterized. Initial mass and energy balances have been calculated based on this system, yielding useful parameters for future economic and design studies.

Bridgeman, T. G., L. I. Darvell, et al. (2007). "Influence of particle size on the analytical and chemical properties of two energy crops." Fuel 86(1-2): 60-72.

Two energy crops (switchgrass and reed canary grass) have been processed using ball mills and divided into two size fractions (less than 90 mum and 90-600 mum) and analysed using an array of analytical techniques including proximate and ultimate analysis, metal analysis, calorific value determination, and plant component analysis (cellulose, lignin and hemicellulose contents). The results indicate that smaller particles of the two grasses have a significantly higher concentration of inorganic matter and moisture content than larger particles. In contrast the larger size fractions had a higher carbon content, and lower nitrogen content, with a resulting higher calorific value. The volatile content was also higher in the larger size fraction. The composition of the organic content varied between the two size fractions, most noticeable was the difference in cellulose concentration which was approximately 50% higher in the greater than 90 mum sample. Two laboratory scale techniques, thermogravimetric analysis (TGA) and pyrolysis-GC-MS (py-GC-MS), were used to study the significance of these differences in thermal conversion. In py-GC-MS of reed canary grass, and switchgrass to a lesser extent, the amounts of cellulose and lignin decomposition products were higher for the larger particle size fraction. The differences in cellulose contents were also apparent from the TGA studies, where different mass losses were seen in the cellulose decomposition region of the two size fractions. From the results of these two techniques it was concluded that the differences in ash, and therefore catalytic metal contents, between the two size fractions, resulted in lower pyrolysis temperatures, lower char combustion temperatures, and higher yields of catalytic pyrolysis decomposition products for the smaller size fractions. The implications of the results are discussed in terms of the bio-oil quality in fast pyrolysis and the predicted behaviour of the ash in combustion. It is suggested that pre-treatment by milling is one route that might be used routinely as a feedstock quality improvement strategy in integrated biomass conversion processes. copy 2006 Elsevier Ltd. All rights reserved.

Mohan, D., C. U. Pittman Jr, et al. (2006). "Pyrolysis of wood/biomass for bio-oil: A critical review." Energy & Fuels 20(3): 848-889.
Fast pyrolysis utilizes biomass to produce a product that is used both as an energy source and a feedstock for chemical production. Considerable efforts have been made to convert wood biomass to liquid fuels and chemicals since the oil crisis in mid-1970s. This review focuses on the recent developments in the wood pyrolysis and reports the characteristics of the resulting bio-oils, which are the main products of fast wood pyrolysis. Virtually any form of biomass can be considered for fast pyrolysis. Most work has been performed on wood, because of its consistency and comparability between tests. However, nearly 100 types of biomass have been tested, ranging from agricultural wastes such as straw, olive pits, and nut shells to energy crops such as miscanthus and sorghum. Forestry wastes such as bark and thinnings and other solid wastes, including sewage sludge and leather wastes, have also been studied. In this review, the main (although not exclusive) emphasis has been given to wood. The literature on wood/biomass pyrolysis, both fast and slow, is surveyed and both the physical and chemical aspects of the resulting bio-oils are reviewed. The effect of the wood composition and structure, heating rate, and residence time during pyrolysis on the overall reaction rate and the yield of the volatiles are also discussed. Although very fast and very slow pyrolyses of biomass produce markedly different products, the variety of heating rates, temperatures, residence times, and feedstock varieties found in the literature make generalizations difficult to define, in regard to trying to critically analyze the literature. copy 2006 American Chemical Society.

Thermochemical – Pyrolysis – Slow

Gaunt, J. L. and J. Lehmann (2008). "Energy balance and emissions associated with biochar sequestration and pyrolysis bioenergy production." Environmental Science & Technology 42(11): 4152-4158.
The implications for greenhouse gas emissions of optimizing a slow pyrolysisbased bioenergy system for biochar and energy production rather than solely for energy production were assessed. Scenarios for feedstock production were examined using a life-cycle approach. We considered both purpose grown bioenergy crops (BEC) and the use of crop wastes (CW) as feedstocks. The BEC scenarios involved a change from growing winter wheat to purpose grown miscanthus, switchgrass, and corn as bioenergy crops. The CW scenarios consider both corn stover and winter wheat straw as feedstocks. Our findings show that the avoided emissions are between 2 and 5 times greater

when biochar is applied to agricultural land (2-19 Mg CO2 ha-1 y-1) than used solely for fossil energy offsets. 41-64% of these emission reductions are related to the retention of C in biochar, the rest to offsetting fossil fuel use for energy, fertilizer savings, and avoided soil emissions other than CO2. Despite a reduction in energy output of approximately 30% where the slow pyrolysis technology is optimized to produce biochar for land application, the energy produced per unit energy input at 2-7 MJ/MJ is greater than that of comparable technologies such as ethanol from corn. The C emissions per MWh of electricity production range from 91-360 kg CO2 MWh -1, before accounting for C offset due to the use of biochar are considerably below the lifecycle emissions associated with fossil fuel use for electricity generation (600-900 kg CO2 MWh-1). Low-temperature slow pyrolysis offers an energetically efficient strategy for bioenergy production, and the land application of biochar reduces greenhouse emissions to a greater extent than when the biochar is used to offset fossil fuel emissions. copy 2008 American Chemical Society.

Transesterification Hossain, A. B. M. S., A. Salleh, et al. (2008). "Biodiesel fuel production from algae as renewable energy." American Journal of Biochemistry & Biotechnology 4(3): 250-254.

Biodiesel is biodegradable, less CO2 and NOx emissions. Continuous use of petroleum sourced fuels is now widely recognized as unsustainable because of depleting supplies and the contribution of these fuels to the accumulation of carbon dioxide in the environment. Renewable, carbon neutral, transport fuels are necessary for environmental and economic sustainability. Algae have emerged as one of the most promising sources for biodiesel production. It can be inferred that algae grown in CO 2-enriched air can be converted to oily substances. Such an approach can contribute to solve major problems of air pollution resulting from CO 2 evolution and future crisis due to a shortage of energy sources. This study was undertaken to know the proper transesterification, amount of biodiesel production (ester) and physical properties of biodiesel. In this study we used common species Oedogonium and Spirogyra to compare the amount of biodiesel production. Algal oil and biodiesel (ester) production was higher in Oedogonium than Spirogyra sp. However, biomass (after oil extraction) was higher in Spirogyra than Oedogonium sp. Sediments (glycerine, water and pigments) was higher in Spirogyra than Oedogonium sp. There was no difference of pH between Spirogyra and Oedogonium sp. These results indicate that biodiesel can be produced from both species and Oedogonium is better source than Spirogyra sp. copy 2008 Science Publications.

Miao, X. and Q. Wu (2007). "Study on preparation of biodiesel from microalgal oil." Taiyangneng Xuebao/Acta Energiae Solaris Sinica 28(2): 219-222.

Biodiesel fuels have received considerable attention in recent years as a renewable, biodegradable, and nontoxic fuel. Chlorella protothecoides is a microalgae that can be photoautotrophically or heterotrophically grown under different regetal conditions. Heterotrophic growth of Chlorella protothecoides resulted in the accumulation of high lipid content of 55% in cells, which was about 4 times that in autotrophic cells (14%). Large amount of microalgal oil was efficiently extracted from these heterotrophic cells by using n-hexane. Good quality of biodiesel was obtained from heterotrophic microalagl oil under the conditions of acid catalyst with 56:1 molar ratio of methanol to oil at temperature of 30 degree C in about 4 h of reaction time. The biodiesel was characterized by a density of 0.864 kg/L, the viscosity of 5.2 multiplied by 10-4 (40 degree C) and a heating value of 41 MJ kg-1. These properties are comparable to conventional diesel. The biodiesel from microalgal oil showed much lower cold filter plugging point of -11 degree C in comparison with the diesel fuel, which is better for engine start at lower temperature. Developing high lipid content microalgae or 'bioengineering microalgae' would be a new and the main way for biodiesel production in the future.

Xiong, W., X. Li, et al. (2008). "High-density fermentation of microalga Chlorella protothecoides in bioreactor for microbio-diesel production." Applied Microbiology & Biotechnology 78(1): 29-36.
Agal-fermentation-based microbio-diesel production was realized through highcell-density fermentation of Chlorella protothecoides and efficient transesterification process. Cell density achieved was 16.8 g l-1 in 184 h and 51.2 g l-1 in 167 h in a 5-l bioreactor by performing preliminary and improved fedbatch culture strategy, respectively. The lipid content was 57.8, 55.2, and 50.3% of cell dry weight from batch, primary, and improved fed-batch culture in 5-l bioreactor. Transesterification was catalyzed by immobilized lipase, and the conversion rate reached up to 98%. The properties of biodiesel from Chlorella were comparable to conventional diesel fuel and comply with US standard for Biodiesel. In a word, the approach including high-density fermentation of Chlorella and enzymatic transesterification process were set up and proved to be a promising alternative for biodiesel production. copy 2007 Springer-Verlag.

Ultrasound Montalbo-Lomboy, M., G. Srinivasan, et al. Influence of ultrasonics in ammonia steeped switchgrass for enzymatic hydrolysis. 2007 ASABE Annual International Meeting, Technical Papers 2007 ASABE Annual International Meeting, Technical Papers. v 13 BOOK 2007. 12p 076231.
The bioconversion of lignocellulosic materials into fuels is of great environmental and economic importance, because of the large amounts of feedstock (est. over 1 billion tons per year), the potentially low cost of this feedstock, and the potentially high net energy balance the overall process. Switchgrass (Panicum virgatum L.) is a candidate dedicated lignocellulosic feedstock in the US. However, lignocellulosic materials, including switchgrass, are hampered by the recalcitrance of lignocellulose to enzymatic degradation into fermentable sugars. Various types of pretreatment have been developed to overcome this recalcitrance. In this study, we examined sequential ammonia-steeping and ultrasound pretreatment of switchgrass. The experimental variables included ultrasound energy dissipation and source amplitude, biomass concentrations, and antibacterial agents. Specifically, the 35-mL samples received either 2000 J or 5000 J, while biomass concentration was at 10% and 30% (mass basis). Antibacterial agents were employed to determine the extent to which sugars were being metabolized by naturally occurring bacteria in the unsterilized pretreated

samples. Analytical glucose analysis was conducted to verify the amount of fermentable sugars released and low-vacuum SEM was used to establish the physical effect of ultrasonics on the biomass. The sequential ammonia steeping-ultrasonic pretreatment released about 10% more fermentable sugars than did ammonia steeping alone. However, the net energy balance (additional chemical in free sugars minus energy consumption of ultrasound process) was not favorable - this contrasts with Grewell's work using ultrasonics for enhancing sugar release from starches. We recommend further investigations on re-evaluating the design and conditions which could make ultrasonic work better as a lignocellulosic pretreatment.

References

Ley de Promoción y Desarrollo de Bioenergéticos. February 2008. Mexico
Potenciales y viabilidad del uso de bioetanol y biodiesel para el transporte en México. November 2006. Secretaría de Energía México. Mexico.

Programa de producción sustentable de insumos para bioenergéticos y de desarrollo científico y tecnológico. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. 2008. Mexico.

Petróleos Mexicanos Statistical Yearbook 2009. Petróleos Mexicanos. 2009. Mexico.
"Iniciativas PEMEX, uso de biocombustibles" Petróleos Mexicanos. October 2009. Presentation at the 2nd Biofuels Forum. Guanajuato, Mexico.

"Factores determinantes para el desarrollo de biocombustibles en Brasil y EEUU y sus implicaciones para México" SE2T International, Ltd. May 2007. Presentation at the seminar: Retos para el desarrollo de biocombustibles en México. Mexico City, Mexico.

"Regulación y certificación de biocombustibles en el mundo" The International Council of Clean Transportation. May 2007. Presentation at the seminar: Retos para el desarrollo de biocombustibles en México. Mexico City, Mexico.

"Eficiencia energética y costos económicos de la producción de biocombustibles" Comisión Nacional para el Ahorro de Energía, México. May 2007. Presentation at the seminar: Retos para el desarrollo de biocombustibles en México. Mexico City, Mexico.

"Externalidades asociadas a la producción y uso de bioetanol" Instituto Nacional de Ecología, México. May 2007. Presentation at the seminar: Retos para el desarrollo de biocombustibles en México. Mexico City, Mexico.

D.W. Monsma, A high growth strategy for ethanol. Aspen Institute.

N. Greene, Ethanol and the environment: delivering on the promise of a sustainable biofuels. Aspen Institute.

Petróleo, biocombustibles y alimentos. Fundación Colosio AC. November 2007. Mexico.

Sustainable bioenergy: a framework for decision makers". United Nations. 2000.

International Energy Agency, World Energy Outlook 2008. 2008.

L.F. Leite, J.N. Noschang, J.V. Bevilaqua, Biorefineries and biofuels: current activities and future vision of Petrobras.

Biocombustibles, cultivos energéticos y soberanía alimentaria en América Latina. Genesis. Quito, Ecuador.

Effects of fuel ethanol use on fuel-cycle energy and greenhouse gas emissions. Center for Transportation Research Argonne National Laboratory.". Chicago, US.

Biofuels for transport: an international perspective. International Energy Agency. June 2005.

http://www.inegi.gob.mx

http://attra.ncat.org/new_pubs/attra-pub/soilmgmt.html

Brady, N.C. and R.R. Weil. 2002. Soil Organic Matter pp.353-385 in Elements of the Nature and Properties of Soils. Pearson Prentice Hall, Upper Saddle River, NJ.

http://www.notill.org/KnowledgeBase/Reicosky_WC01.PDF

http://www.extension.umn.edu/distribution/cropsystems/components/7399_02.html

http://www.monsanto.com/biotech-gmo/asp/topic.asp?id=ConservationTillage

http://cropwatch.unl.edu/input$/notill_irrigation.htm

Carbon sequestration in two Brazilian Cerrado soils under no-till Bayer, C | Martin-Neto, L | Mielniczuk, J | Pavinato, A | Dieckow, J Soil and Tillage Research [Soil Tillage Res.]. Vol. 86, no. 2, p.237-245. Apr 2006.

http://researchnews.osu.edu/archive/notill.htm

K. Y. Chan, An overview of some tillage impacts on earthworm population abundance and diversity -- implications for functioning in soils, Soil and Tillage Research, Volume 57, Issue 4, January 2001, Pages 179-191, [1]

http://www.jswconline.org/content/39/5/327.abstract

D.L. Beck, J.L. Miller, and M.P. Hagny "Successful No-Till on the Central and Northern Plains "
http://www.dakotalakes.com/Publications/asa10_98.pdf

http://ecat.sc.egov.usda.gov/Fuel.aspx

http://www.extension.iastate.edu/CropNews/2009/0313alkaisihanna.htm
http://www.notill.org/KnowledgeBase/03_economics_derpsch.pdf

http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=176317

http://www.extension.umn.edu/extensionnews/2005/carboncredits07.html

http://nfu.org/issues/environment/carbon-credits
www.english-heritage.org.uk/upload/pdf/030725_RippingUpHistory.pdf

July 2003 English Heritage - "Ripping Up History"
Pratap S. Birthal and O. P. Sharma "Integrated Pest Management in Indian Agriculture"

Peter Gruhn, Francesco Goletti, and Montague Yudelman "Integrated Nutrient Management, Soil Fertility, and Sustainable Agriculture: Current Issues and Future Challenges "

Kowalewicz, A. and M. Wojtyniak, Alternative fuels and their application to combustion engines. Proceedings of the Institution of Mechanical Engineers Part D-Journal of Automobile Engineering, 2005. 219(D1): p. 103-125.

Altin, R., S. Cetinkaya, and H.S. Yucesu, The potential of using vegetable oil fuels as fuel for diesel engines. Energy Conversion and Management, 2001. 42(5): p. 529-538.

Agarwal, A.K., Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Progress in Energy and Combustion Science, 2007. 33: p. 233-271.

Schumacher, L., W. Hires, and J. Krahl. Cummins 5.9L Biodiesel Fueled Engines. in Proceedings of the Second Biomass Conference of the Americas. 1995. Portland, OR.

Assessment of the Operation of Vehicles in the Australian Fleet on Bioethanol Blend Fuels. 2007, Orbital Australia Pty Ltd. p. 170.

Schumacher, et al. Fueling Diesel Engines with Methyl-Ester Soybean Oil. in Liquid Fuels from Renewable Resources: Proceedings of an Alternative Energy Conference. 1992. Nashville, TN: American Society of Agricultural Engineers.

Reece, D. and C. Peterson, A Report on the Idaho On-road Vehicle Test with RME and Neat Rapeseed Oil as an Alternative to Diesel Fuel. ASAE Paper, 1993. 935018.

Marshall and F. William, Effects of Methyl Esters of Tallow and Grease on Exhaust Emissions and Performance of a Cummins L10 Engine, IIT Research Institute, National Institute for Petroleum and Energy Reserach: Bartlesville, OK.

Scholl, K. and S. Sorenson, Combustion of soyabean oil methyl ester in a direct injection diesel engine. SAE Paper, 1993. 930934.

Radich, A., Biodiesel Performance, Costs and Use.

Pfeiffer, P., A. Zabel, and A. Belser, The Use of Biodiesel in Vermont: An Introduction to an Alternative Fuel Source for the State of Vermont. 2007, Rockefeller Center at Dartmouth College.

Agarwal, A., J. Bijwe, and L. Das, Wear assessment in biodiesel fuelled compression ignition engine. Journal of Engine Gas Turbine Power (ASME J), 2003. 125(3): p. 820-826.

Agarwal, A., J. Bijwe, and L. Das, Effect of biodiesel utilization on wear of vital parts in compression ignition engine. Journal of Gas Turbine Power (ASME J), 2003. 125(2): p. 604-611.

Gerpen, J.H.V., C.L. Peterson, and C.E. Goering. Biodiesel: An Alternative Fuel for Compression Ignition Engines. in The 2007 Agricultural Equipment Technology Conference. 2007. Louisville, Kentucky.

Tyson, K.S., *Biodiesel Handling and Use Guidelines (3rd edition)*. 2006, Energy Efficiency and Renewable Energy, U.S. Department of Energy.

Sem, T.R., Effect of Various Lubricating Oils on Piston Deposits in Biodiesel Fueled Engines. SAE Paper, 2004. 2004-01-0098.

Weldel, R.V., Technical Handbook for Marine Biodiesel. 1999.

Gerpen, J.V., Biodiesel Production and Fuel Quality.

Wichmann, H. and M. Bahadir, BIo-based ester oils for use as lubricants in metal working. Clean-Soil Air Water, 2007. **35**(1): p. 49-51.

Ribeiro, N.M., et al., The role of additives for diesel and diesel blended (Bioethanol or

biodiesel) fuels: A review. Energy & Fuels, 2007. **21**(4): p. 2433-2445.
Gray, K.A., L.S. Zhao, and M. Emptage, *Biobioethanol.* Current Opinion in Chemical Biology, 2006. **10**(2): p. 141-146.

RFA and R.F. Association, *Fuel Bioethanol.* 2005.

Poulopoulos, S.G., D.P. Samaras, and C. Philippopoulos, Regulated and unregulated emissions from an internal combustion engine operating on bioethanol-containing fuels. Atmospheric Environment, 2001. 35(26): p. 4399-4406.

Taniguchi, S., K. Yoshida, and Y. Tsukasaki, Feasibility Study of f to A Direct Injection Gasoline Engine. SAE Paper, 2007. 2007-01-2037.

Yuksel, F. and B. Yuksel, The use of bioethanol-gasoline blend as a fuel in an SI engine. Renewable Energy, 2004. 29(7): p. 1181-1191.

Brusstar, M. and M. Bakenhus, Economical, high-efficiency engine technologies for alcohol fuels.

Niven, R.K., Bioethanol in gasoline: environmental impacts and sustainability review article.

Renewable & Sustainable Energy Reviews, 2005. 9(6): p. 535-555.

Lapuerta, M., O. Armas, and R. Garcia-Contreras, Stability of diesel-biobioethanol blends for use in diesel engines. Fuel, 2007. 86(10-11): p. 1351-1357.

CSIRO, B., ABARE, Appropriateness of a 350 Million Litre Biofuels Target. 2003.

Bioethanol Low Sulfur diesel & biodiesel: The good, the bad & the solutions for marine engines.

Ozone-Forming Potential of Reformulated Gasoline. 1999, National Research Council.

Magnusson, R., C. Nilsson, and B. Andersson, Emissions of aldehydes and ketones from a two-stroke engine using bioethanol and bioethanol-blended gasoline as fuel. Environmental Science & Technology, 2002. 36(8): p. 1656-1664.

Guidebook for Handling, Storing & Dispensing Fuel Bioethanol, US Department of Energy.

Davis, G.W. and E.T. Heil, The Development and Performance of a High Blend Bioethanol Fueled Vehicle. SaE Paper, 2000. 2000-01-1602.

Radetzki, Marian, A Handbook of Primary Commodities in the Global Economy, Cambridge University Press, 2008.

Rakopoulos, C.D., K.A. Antonopoulos, and D.C. Rakopoulos, Experimental heat release analysis and emissions of a HSDI diesel engine fueled with bioethanol-diesel fuel blends. Energy, 2007. 32(10): p. 1791-1808.

Shi, X., et al., Emission reduction potential of using bioethanol-biodiesel-diesel fuel blend on a heavy-duty diesel engine.

AtmosphericEnvironment40(2006)2567–2574, 2005.

Hansen, A.C., Q. Zhang, and P.W.L. Lyne, Bioethanol-diesel fuel blends - a review. Bioresource Technology, 2005. 96(3): p. 277-285.

Adetunji, O.A. (2004), An Investigation of the Effects of Gamma Irradiation on the Enzymatic Hydrolysis of Lignocellulosis of Softwood and Hardwood origins", M.Sc. Research thesis.

Bernanke, B.S. (2007) "Monetary Policy under Uncertainty". Speech at the 32nd Annual Economic Policy Conference, Federal Reserve Bank of St. Louis.

Champ, B. and S. Freeman (2001) Modeling Monetary Economies, 2nd ed. Cambridge: Cambridge University Press 49.

Fedoroff, N., and J. Cohen, 1999: *Plants and Populations: Is There Time?* Proceedings of the National Academy of Sciences, USA, 96: 5903-5907.

Gali, J. (2008) Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework. Princeton: Princeton University Press

Greenspan, A. (2007). The Age of Turbulence: Adventures in a New World. New York: Penguin books

Harris, S.E., (2008) Ben Bernanke's FED: The Federal Reserve After Greenspan, Boston, Massachusetts: Harvard Business School Publishing

Isard, P. (2005) Globalization and the International Financial System: What's Wrong and What Can Be Done? Cambridge: Cambridge University Press
Johnson O. E. G. (2002) Financial Risks, Stability, and Globalization, Washington, DC:

International Monetary Fund.
Layokun, S. K., B. O. Solomon, P. K. Nwesigye and P. O. Olutiola (1990) "Hydrolysis of Sawdust by Cellulase Derived from *Aspergillus flavus* linn Isolate NSPR 101" JNSChE 9(1&2), 38 - 45.

Ocampo, J. A. (2005) Beyond Reforms: Structural Dynamics and Macroeconomic Vulnerability.

Ojumu, T.V., Solomon, B.O., Betiku, E., Layokun S.K. and Amigun, B. (2003a): Cellulase Production by *Aspergillus flavus* Linn Isolate NSPR 101 fermented in Sawdust, bagasse and cornnob. African Journal of Biotechnology Vol. 2(6) pp. 150-152.

Ojumu, T.V., Attah-Daniel, B.E., Betiku, E. and Solomon, B.O. (2003b) Auto-hydrolysis of Lignocellulosics Under Extremely Low Sulphuric Acid and High Temperature Conditions in Batch Reactor. Biotechnology and Bioprocess Engineering, 8: 291-293.

Polaski S. (2008). Rising Food Prices, Poverty, and the Doha Round, Carnegie Endowment for International Peace.

Soludo, C. C., and Rao (2002) The Potential Impacts of the New Global Financial Architecture on Poor Countries. Dakar: CODESRIA

Soludo, C.C. (2000) "Globalization Tax and Trade as Remedies to Underdevelopment Traps and Ineffective Aid", In Conference Proceedings of the 12th World Bank Annual Conference on Development Economics, Washington, DC.

Solomon, B. O., S. K. Layokun, P. K. Nwesigye and P. O. Olutiola (1990) "Hydrolysis of Sawdust by Cellulase Derived from Aspergillus flavus linn Isolate NSPR 101: Beyond the initial fast rate period." JNSChE 9(1&2), 46 - 50.

http://allafrica.com/stories/200807100235.html site visited on the 4th December, 2008.

"Plants at the Pump: Biofuels, Climate Change and Sustainability", Brit Chills, Rob Bradley, World Resources Institute, Fig. A, p.3 and Fig. 3, p. 13 based on the studies: Fulton, L. et al. Biofuels for Transport: An International Perspective. Paris, France: International Energy Agency; 2004.

Groode, Tiffany A. and John B. Heywood. Bioethanol: A Look Ahead. Laboratory for Energy and Environment, Massachusetts Institute of Technology. Publication No. LFEE 2007-002 RP.; 2007. Hill, Jason et al. 2006.

"Environmental, economic, and energetic costs and benefits of biodiesel and bioethanol biofuels." Proceedings of the National Academy of Sciences (PNAS), Jul 2006. 103: 11206 – 11210; U.S. Environmental Protection Agency (EPA). 2007.

Greenhouse Gas Impacts of Expanded Renewable and Alternative Fuels Use. EPA420-F-07-035. Washington, DC: EPA Office of Transportation and Air Quality; Worldwatch Institute. 2007.

"Shift Gear to Biofuels" Final report of the VIEWLS project, VIEWLS project, Clear Views on Clean Fuels, which was supported by the European Commission(NNE5-2001-00619), p. 27 – 28

http://www.wtec.org/ConvergingTechnologies/

http://www.singularity.com/

http://www.whitehouse.gov/news/releases/2006/01/20060131-6.html

Nicholas Wade, "Petroleum From Decay? Maybe Not, Study Says," New York Times, September 14, 2004. Previously the deepest hole in the United States was the Berth Rogers gas well in Oklahoma (6 miles). On the Kola Peninsula near Murmansk, a hole was drilled 8 miles in depth; the temperature at the bottom of that hole was 190 degrees C.

K. Otsuka and S. Takenaka, "Production of Hydrogen from Methane by a CO2 Emission-Suppressed Process: Methane Decomposition and Gasification of Carbon Nanofibers," Catalysis Surveys from Asia, June 2004, vol. 8, no. 2, pp. 77-90(14)

http://news.nationalgeographic.com/news/2005/01/0114_050114_solarplastic.html

http://hotrock.anu.edu.au/index.html

http://www.syntheticgenomics.com/

http://www.foresight.org/challenges/energy.html

http://www.space.com/news/ap_060126_russia_moon.html

http://www.esa.int/esaCP/SEMHVXVLWFE_index_0.html

http://www.nada.kth.se/~asa/dysonFAQ.html#WHAT

http://www.aleph.se/Trans/Global/Omega/

http://en.wikipedia.org/wiki/orders_of_magnitude_(power)%20

(http://www.millenium-project.org)

"Petroleum Products Consumption." Energy Information Administration. 10 February 2009.

http://tonto.eia.doe.gov/dnav/pet/xls/PET_PRI_SPT_S1_D.xls

"2006 IMF Global Financial Stability Report." April 2006. International Monetary Fund. 15 August 2008.

http://www.imf.org/external/pubs/ft/GFSR/2006/01/indes.htm

http://www.federalreserve.gov/econresdata/releases/statisticsdata.htm

"Study links oil prices to investor speculation." 11 September 2008. Associated Press. 15 September 2008. http://articles.latimes.com/2008/sep/11/business/fi-oilspec11

"Statistical View of World Energy 2007." British Petroleum. 20 September 2008. http://www.bp.com/sectiongenericarticle.do?categoryId=9023753&contentId=7044109

EIA Data: http://tonto.eia.doe.gov/dnav/pet/hist/rwtcd.htm

Global Outlook for Biofuels : Elena Nekhaev
IEA World Energy Outlook, 2006

Kowalewicz, A. and M. Wojtyniak, Alternative fuels and their application to combustion engines. Proceedings of the Institution of Mechanical Engineers Part D-Journal of Automobile Engineering, 2005. 219(D1): p. 103-125.

Altin, R., S. Cetinkaya, and H.S. Yucesu, The potential of using vegetable oil fuels as fuel for diesel engines. Energy Conversion and Management, 2001. 42(5): p. 529-538.

Balat, M., Production of Biodiesel from Vegetable Oils: A Survey. Energy Sources, 2007 29: p. 895-913.

Strong, C., Evaluation of Biodiesel Fuel: Literature Review. Montana Department of Transportation, 2004.

Technical Recommendations for B20 Fleet Use Based on Existing Data. 2005.

Assessment of the Operation of Vehicles in the Australian Fleet on Ethanol Blend Fuels. 2007, Orbital Australia Pty Ltd. p. 170.

Kodali, D.R., High performance ester lubricants from natural oils. Industrial Lubrication and Tribology, 2002. 54(4): p. 165-170.

RFA and R.F. Association, *Fuel Ethanol.* 2005.
Poulopoulos, S.G., D.P. Samaras, and C. Philippopoulos, Regulated and unregulated emissions from an internal combustion engine operating on ethanol-containing fuels. Atmospheric Environment, 2001. 35(26): p. 4399-4406.

Taniguchi, S., K. Yoshida, and Y. Tsukasaki, Feasibility Study of Ethanol Applications to A Direct Injection Gasoline Engine. SAE Paper, 2007. 2007-01-2037.

Yuksel, F. and B. Yuksel, The use of ethanol-gasoline blend as a fuel in an SI engine. Renewable Energy, 2004. 29(7): p. 1181-1191.
Brusstar, M. and M. Bakenhus, Economical, high-efficiency engine technologies for alcohol fuels.

Niven, R.K., Ethanol in gasoline: environmental impacts and sustainability review article. Renewable & Sustainable Energy Reviews, 2005. 9(6): p. 535-555.

Lapuerta, M., O. Armas, and R. Garcia-Contreras, Stability of diesel-bioethanol blends for use in diesel engines. Fuel, 2007. 86(10-11): p. 1351-1357.

CSIRO, B., ABARE, Appropriateness of a 350 Million Litre Biofuels Target. 2003. Ethanol Low Sulfur diesel & biodiesel: The good, the bad & the solutions for marine engines.

Ozone-Forming Potential of Reformulated Gasoline. 1999, National Research Council.

Magnusson, R., C. Nilsson, and B. Andersson, Emissions of aldehydes and ketones from a two-stroke engine using ethanol and ethanol-blended gasoline as fuel. Environmental Science & Technology, 2002. 36(8): p. 1656-1664.

Davis, G.W. and E.T. Heil, The Development and Performance of a High Blend Ethanol Fueled Vehicle. SaE Paper, 2000. 2000-01-1602.

Kwanchareon, P., A. Luengnaruemitchai, and S. Jai-In, Solubility of a diesel-biodiesel-ethanol blend, its fuel properties, and its emission characteristics from diesel engine. Fuel, 2007. 86(7-8): p. 1053-1061.

Rakopoulos, C.D., K.A. Antonopoulos Experimental heat release analysis and emissions of a HSDI diesel engine fueled with ethanol-diesel fuel blends. Energy, 2007. 32(10): p. 1791-1808.

Shi, X., et al., Emission reduction potential of using ethanol-biodiesel-diesel fuel blend on a heavy-duty diesel engine.

AtmosphericEnvironment40(2006)2567–2574, 2005.

Energy Efficiency and End-Use Technologies of Biodiesel Production

“Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus”, US Department of Agriculture and US Department of Energy, Final Report, May 1998

“Analysis de Cyclo de Vida de Combustibles Alternativos para el Transporte. Phase II. Analisis de Cyclo de vida comparativo del Biodiesel y del Diesel”, Centro de Investigaciones Energeticas, Medioambientales y Tecnológicas, CIEMAT, Ministerio del Medio Ambiente, 2006;

Source: *Nature 444 (December 7, 2006): 673 – 676*

http://allafrica.com/stories/200807100235.htm

Fedoroff, N., and J. Cohen, 1999: *Plants and Populations: Is There Time?* Proceedings of the National Academy of Sciences, USA, 96: 5903-5907.

Gali, J. (2008) Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework. Princeton: Princeton University Press

Harris, S.E., (2008) Ben Bernanke’s FED: The Federal Reserve After Greenspan, Boston, Massachusetts: Harvard Business School Publishing

Isard, P. (2005) Globalization and the International Financial System: What’s Wrong and What Can Be Done? Cambridge: Cambridge University Press

Johnson O. E. G. (2002) Financial Risks, Stability, and Globalization, Washington, DC: International Monetary Fund.

Layokun, S. K., B. O. Solomon, P. K. Nwesigye and P. O. Olutiola (1990) "Hydrolysis JNSChE 9(1&2), 38 - 45.

Nayyar, D. (2002) Governing Globalization: Issues and Institutions. Oxford: Oxford University Press.

Phillips, K. (2008) Bad Money: Reckless Finance, Failed Politics, and the Global Crisis of American Capitalism, New York: The penguin group.

Reily J. and Paltsev S. (2007). Biomass Energy and Competition for Land, Report No. 145.

Solomon, B. O., S. K. Layokun, P. K. Nwesigye and P. O. Olutiola (1990) "Hydrolysis of Sawdust by Cellulase Derived from *Aspergillus flavus* linn Isolate NSPR 101: Beyond the initial fast rate period." JNSChE 9(1&2), 46 – 50.

Classification, Certification and Standardization Including Lifecycle Assessments of Biofuels Steps towards the development of a certification system for sustainable bio-energy trade, Levandowski and Faaij, Biomass and Bioenergy 30, 2005, p.83-106

Overview in recent developments in sustainable biomass certification" , IEA Bioenergy Task 40, 2006, p. 3

"Biofuels for transportation - global potential and implications for sustainable agriculture and energy in the 21st century".

Washington D.C., Worldwatch Institute, commissioned by German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) in cooperation with the Agency for Technical Cooperation (GTZ) and the Agency of Renewable Resources (FNR), WWI, 2006

"Criteria for sustainable biomass production", Netherlands, Projectgroep Duurzame Productie van Biomassa, Cramer et al., 2006;

"The emerging biofuels market: regulatory, trade and development implications", Geneva, United Nations Conference on Trade and Development (UNCTAD), Zarrilli, 2006

LCA Studies for the Harmonization of International Biofuels Sustainability Assessment

"Plants at the Pump: Biofuels, Climate Change and Sustainability", Brit Chills, Rob Bradley, World Resources Institute, Fig. A, p.3 and Fig. 3, p. 13 based on the studies: Fulton, L. et al. Biofuels for Transport: An International Perspective. Paris, France: International Energy Agency; 2004.

"A Look Ahead". Laboratory for Energy and Environment, Massachusetts Institute of Technology. Publication No. LFEE 2007-002 RP, 2007. Hill, Jason et al. 2006.

"Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels." Proceedings of the National Academy of Sciences (PNAS), Jul 2006. 103: 11206 – 11210; U.S.

Environmental Protection Agency (EPA). 2007. Greenhouse Gas Impacts of Expanded Renewable and Alternative Fuels Use. EPA420-F-07-035. Washington, DC: EPA Office of Transportation and Air Quality; Worldwatch Institute. 2007.

"Shift Gear to Biofuels" Final report of the VIEWLS project, VIEWLS project, Clear Views on Clean Fuels, which was supported by the

European Commission (NNE5 2001 00619), p. 27 - 28

"Energy and GhG balances of biofuels and conventional fuels", ADEME, DIREM, Report according to Ecobilan-PricewaterhouseCoopers work, November 2002.

"Emissions of greenhouse gases in a life cycle perspective and use of energy and land in production of RME from Swedish rapeseed", Swedish Institute for Food and Biotechnology, 2008

The EU Biofuels Policy and Regulatory Landscape
Directive of the European Parliament and the Council on the promotion of the use of biofuels or other renewable fuels in transport, 2003/30/EC, 8 Mai 2003

The "Biofuels Directive" set that the minimum percentage of biofuels or other renewable fuels put on the market in every Member State is 2% for 2005; 5,75% for 2010, and 10% for 2020, calculated on energy content.

Council Directive 2003/96/EC restructuring the Community framework for the taxation of energy products and electricity, 27 October 27, 2003

Sustainability Criteria for Biomass and Biofuels
Forest Stewardship Council "FSC Principles and Criteria for Forest Stewardship", 2002, p. 5

Final RSPO Certification System Document , May 2007, p. 27

Roundtable on Sustainable Biofuels RSB "Version Zero", 2008, p. 3

Final RSPO Certification System Document », May 2007, p. 27 and p. 35

Roundtable on Sustainable Biofuels, Ecole Polytechnique Fédérale de Lausanne, 2008, p. 7

Challenges and Opportunities
Roadmap for Bioenergy and Biobased Products in the United States, October 2007

From 1st to 2nd Gneration Biofuel Technologies, An Overview of Current Industry and RD&D Activities, IEA Bioenergy, International Energy Agency, November 2008

National Biofuels Action Plan, Biomass Research and Development Board, U.S. Government, October 2008

Member Committees of the World Energy Council

Albania
Algeria
Argentina
Australia
Austria
Belgium
Botswana
Brazil
Bulgaria
Cameroon
Canada
China
Colombia
Congo (Democratic Republic)
Côte d'Ivoire
Croatia
Cyprus
Czech Republic
Denmark
Egypt (Arab Republic)
Estonia
Ethiopia
Finland
France
Germany
Ghana
Greece
Hong Kong, China
Hungary
Iceland
India
Indonesia
Iran (Islamic Republic)
Ireland
Israel
Italy
Japan
Jordan
Kazakhstan
Kenya
Korea (Rep.)
Kuwait
Latvia
Lebanon
Libya/GSPLAJ
Lithuania
Luxembourg
Macedonia (Republic)
Mexico
Monaco
Mongolia
Morocco
Namibia
Nepal
Netherlands
New Zealand
Niger
Nigeria
Norway
Pakistan
Paraguay
Peru
Philippines
Poland
Portugal
Qatar
Romania
Russian Federation
Saudi Arabia
Senegal
Serbia
Slovakia
Slovenia
South Africa
Spain
Sri Lanka
Swaziland
Sweden
Switzerland
Syria (Arab Republic)
Taiwan, China
Tajikistan
Tanzania
Thailand
Trinidad & Tobago
Tunisia
Turkey
Ukraine
United Arab Emirates
United Kingdom
United States
Uruguay
Yemen

World Energy Council
Regency House 1-4 Warwick Street
London W1B 5LT United Kingdom
T (+44) 20 7734 5996
F (+44) 20 7734 5926
E info@worldenergy.org
www.worldenergy.org

ISBN: 978 0 946121 03 8

For sustainable energy.