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Sustainable Biofuels for the Transport Sector

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TABLE OF CONTENTS

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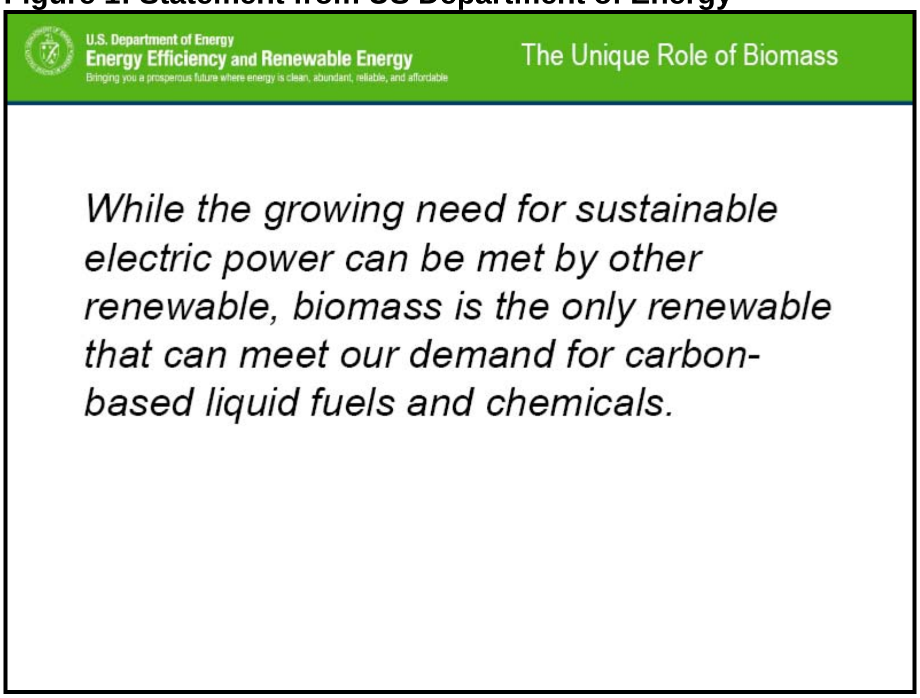
1. INTRODUCTION

The transport sector is almost fully dependent on oil-derived products and in both the United States and in Europe this sector contributes with about one third of total energy consumption and about 30 % of the CO_2 emissions. The transport sector is forecasted to contribute with 90 % of the increase in CO_2 emissions projected for EU in 2010. With the increasing use of oil for transport in China, India and other Asian countries the rush for oil has resulted in increasing prices on oil and a push for production of oil substitutes.

Finding alternatives is a key issue and biofuels are expected to be the easiest alternative fuel as no significant changes in the infrastructure or in established vehicles and engines are required. Biomasses play a unique role as raw materials for the production of transport fuels as outlined by US Department of Energy, figure 1.

Figure 1: Statement from US Department of Energy



2. 1 GENERATION VERSUS 2 GENERATION BIOFUELS

It is important to understand that biofuels are not always “bio”- and in some situations large scale production will lead to a larger over-all use of fossil fuel and thereby a larger emission of carbon dioxide. Biodiesel produced from rape seed and bioethanol produced from corn might be questionable when it comes to the net energy produced. Furthermore, production of these types of biofuels will occupy land, which might be used for food production and it can further lead to loss of rainforest or deforestation in parts of the world where the new opportunities opens for new developments.

Biofuels is a common description for fuels made from biological materials. Normally it accounts for biodiesel produced from rape seed, soybeans and palm-seeds - or bioethanol produced from sugar cane, corn or wheat. Using conventional crops for producing a biofuel is known as 1 Generation biofuels compared to 2 Generation biofuels where the raw material will be agricultural or wood residues, waste or other lignocellulosic materials such as energy crops, figure 2.

Figure 2: Bioethanol productions technologies

Current technology:

Starch-based ethanol

Biomass: Corn, grain, sugar

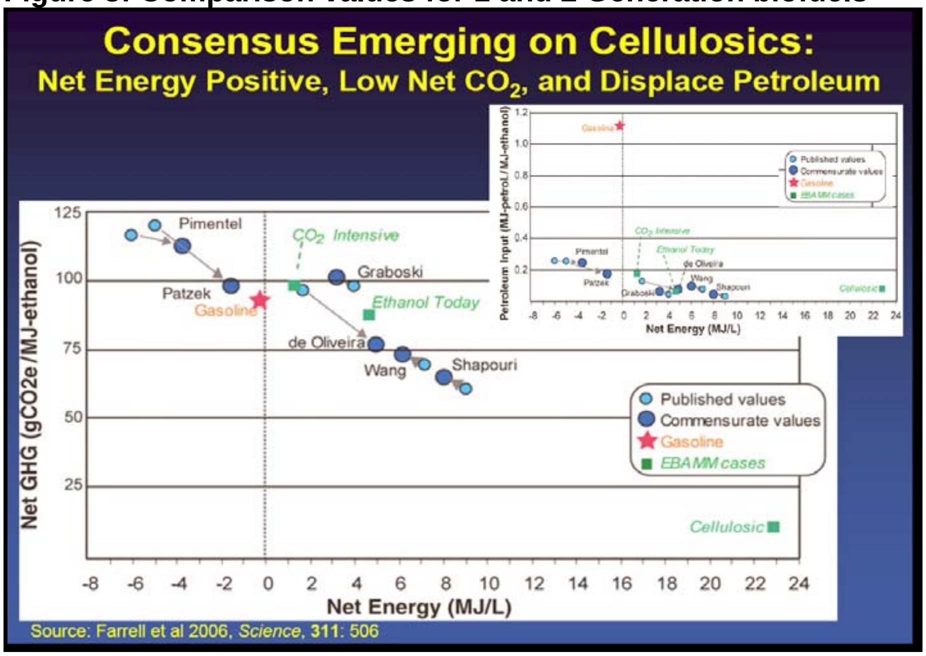
The future technology:

Lignocellulose based ethanol

Biomass: Corn stover, straw, bagasse, wood etc.

Producing biofuels from a residue results in a much higher net energy outcome compared to producing biofuels by 1 Generation technology. The reason is a much higher energy use for making the raw material in 1 Generation technology compared to using a waste material where the main energy use comes from collection and processing of the material during production of biofuels. Figure 3 shows a comparison of the values for 1 and 2 Generation biofuels, which have been published by the indicated authors.

Figure 3: Comparison values for 1 and 2 Generation biofuels



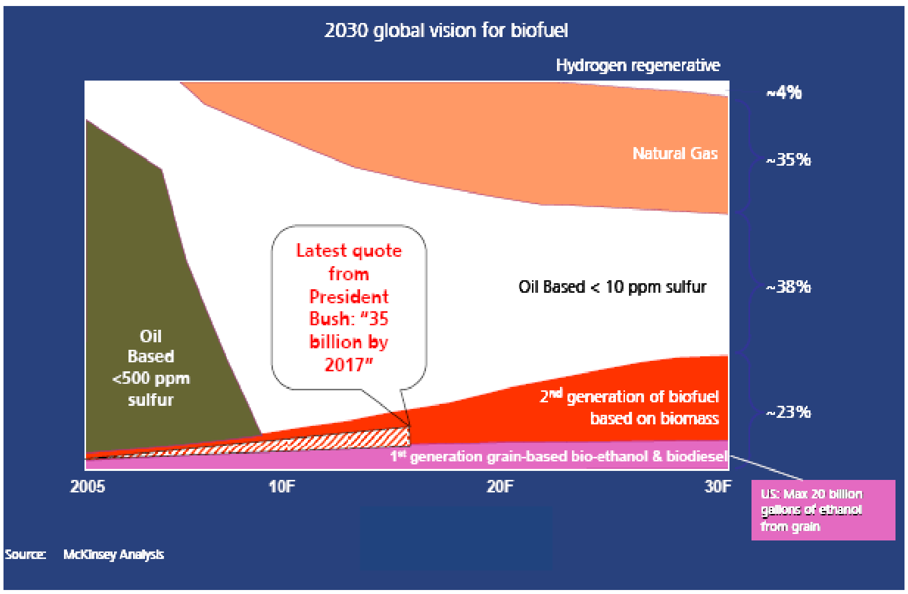
Source: Farrell et al 2006, *Science*, 311: 506

The figure shows the relationship between green house gas emission and net energy per liter biofuels compared to gasoline (red star). The figure represents some of the major studies, which have been done over the last 10 years. As can be seen from the figure the ethanol we produce today results in a slight decrease in green house gas emission compared to gasoline- and the net energy of using a biofuels is low compared to gasoline. Using lignocellulosics as raw material will, however, be much more favorable as shown by the green square fare to the right in the figure.

3. POLITICAL GOALS FOR 2 GENERATION BIOFUELS IN USA AND EU

The competition for land between food and fuel production has increasingly been sharpened during the last year. The so-called "tortilla-crisis" is known to the broad public of the world and recently Cuba's president declared "war" against bioethanol. In accordance with this President Bush has declared a 20 % reduction of gasoline usage in the United States over the next ten years. To reach this goal 35 bn Gallons of bioethanol is needed by which 20 bn Gallons are ethanol from cellulosics in 2017.

Figure 4: 2030 global visions for 2 Generation biofuels



Source: Mackinsey Analysis

The quantitative policy for promoting biofuels has also been imposed in the European setting. EU has prolonged there current goal of using 5.75% biofuels in year 2010 to a production target of 10% by volume in year 2020. As for USA, EU has further set the scene for conversion to 2 Generation biofuels. The goal is now subject to: "the availability of sustainable 2 Generation biofuels becoming commercially available".

While the technology for 1 Generation biofuels from sugar, corn or oil-producing crops are well known the use of lignocellulosic biomass makes use of several new process steps, which is not matured to the same extent. Department of Energy (DOE) in US published in July 2006 a "roadmap" for bringing 2 Generation bioethanol to the market. The 200-page scientific "roadmap" cites recent advances in biotechnology that have made cost-effective production of ethanol from cellulose, or inedible plant fiber, an attainable goal. The report outlines a detailed research plan for developing new technologies to transform cellulosic ethanol into an economically viable transportation fuel. In accordance with this roadmap many parts of the technology needs to be improved including better energy crops, better pretreatment methods, better hydrolysis including better enzymes, better fermentation microbes and processes etc.

DOE is currently investing a large amount of funds in lowering the cost of 2 Generation biofuels through a directed research program (the GTL Bioenergy Centers - with more than 400 mill $) and the demonstration program where 6 projects has just approved for a total of up to 385 mill $, see table 1.

Table 1:
The six selected cellulosic ethanol projects for DOE funding, February 2007

Project	**Description**
Abengoa Bioenergy **Biomass** of Kansas, LLC of Chesterfield, Missouri, up to $76 million.	The proposed plant will be located in the state of Kansas. The plant will produce 11.4 million gallons of ethanol annually and enough energy to power the facility, with any excess energy being used to power the adjacent corn dry grind mill. The plant will use 700 tons per day of corn stover, wheat straw, milo stubble, switchgrass, and other feedstocks.
ALICO, Inc. of LaBelle, Florida, up to $33 million.	The proposed plant will be in LaBelle (Hendry County), Florida. The plant will produce 13.9 million gallons of ethanol a year and 6,255 kilowatts of electric power, as well as 8.8 tons of hydrogen and 50 tons of ammonia per day. For feedstock, the plant will use 770 tons per day of yard, wood, and vegetative wastes and eventually energycane.
BlueFire Ethanol**, Inc.** of Irvine, California, up to $40 million.	The proposed plant will be in Southern California. The plant will be sited on an existing landfill and produce about 19 million gallons of ethanol a year. As feedstock, the plant would use 700 tons per day of sorted green waste and wood waste from landfills.
Poet Energy (formerly **Broin Companies**) of Sioux Falls, South Dakota, up to $80 million.	The plant is in Emmetsburg (Palo Alto County), Iowa, and after expansion, it will produce 125 million gallons of ethanol per year, of which roughly 25 percent will be cellulosic ethanol. For feedstock in the production of cellulosic ethanol, the plant expects to use 842 tons per day of corn fiber, cobs, and stalks.
Iogen Biorefinery Partners, LLC, of Arlington, Virginia, up to $80 million.	The proposed plant will be built in Shelley, Idaho, near Idaho Falls, and will produce 18 million gallons of ethanol annually. The plant will use 700 tons per day of agricultural residues including wheat straw, barley straw, corn stover, switchgrass, and rice straw as feedstocks.,
Range Fuels (formerly Kergy Inc.) of Broomfield, Colorado, up to $76 million.	The proposed plant will be constructed in Soperton (Treutlen County), Georgia. The plant will produce about 40 million gallons of ethanol per year and 9 million gallons per year of methanol. As feedstock, the plant will use 1,200 tons per day of wood residues and wood based energy crops.

4. NEW POLICY NEEDED FOR PROMOTION OF SUSTAINABLE BIOFUELS

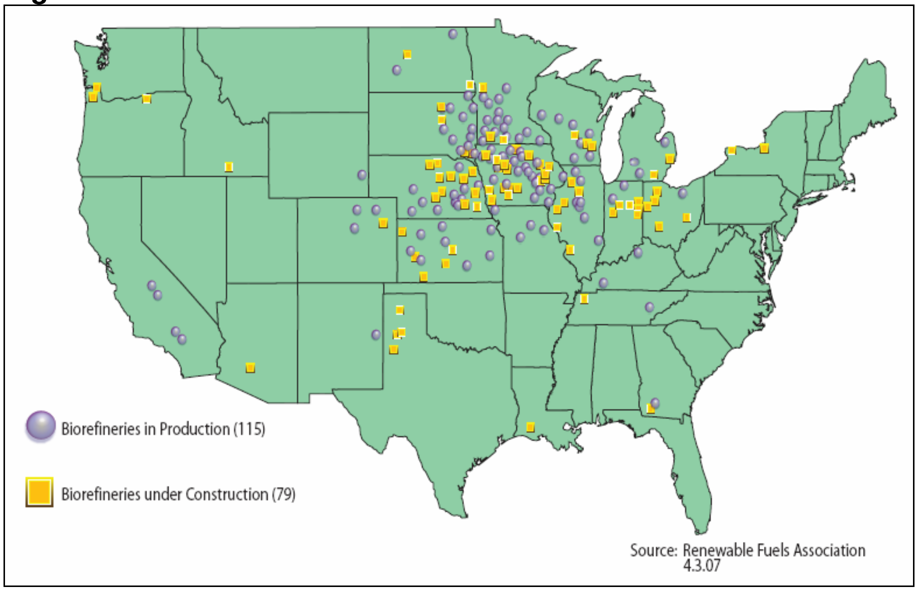
The quantitative policy does not contain direct goals for sustainability and to ensure this additional regulation will be necessary. New policies based on quality of biofuels has for instance been proposed in California in January 2007 by "Low carbon standards" where "Well to Wheel greenhouse gas emissions per liter of transport fuel has been defined with a 10% reduction in year 2020 compared to today. To meet these goals, biofuels produced with 2 Generation technology will have a much higher value compared to biofuels from 1 Generation technology due to the lower green house gas emission by this type of biofuel (80% compared to 20% when produced from corn). Similar targets are currently being discussed in the EU Commission where lifecycle green house gas targets for petrol and diesel could impose increased use of sustainable biofuels over less-sustainable biofuels. Options for reducing the green house gas burden from the transport sector with 10% are to improve the oil production process but this will only give between 1-2% decreases.

The major impact can only be met by sing efficient biofuels. The burden of proof will lie with the fuel supplier and an audited reporting system will be necessary to ensure that the introduced fuel in reality has a lower green house gas emission as previous used fuel. This will demand that biofuels will need a ***climate certification***. A climate quality approach to transport fuel will tackle many problems at the market level rather than at the end of the pipe. This approach can further be improved to avoid problems such as a decrease in biodiversity, competition for resources etc. when producing biofuels.

5. ESTIMATED BIOFUELS PRODUCTION IN USA AND EU IN THE FUTURE

Profit within 1 Generation bioethanol production has been substantial during the last 5 years in USA and many factories have been established or are under construction at the moment. Figure 5 shows the map over bioethanol facilities in USA both the ones in operation and the ones under construction.

Figure 5: Bioethanol facilities in USA



The EU's production of biofuels amounted to 2.4 million tonnes in 2004, approximately 0.8% of EU gasoline and diesel consumption. Bioethanol totalled 0.5 million tonnes and biodiesel 1.9 million tonnes. In Europe use of biodiesel has over-sized the use of bioethanol in a number of EU countries such as Germany and Austria. However, bioethanol production from grain is in place in many EU countries such as Spain, France, Sweden and Germany. The number of factories is, however, small compared to the amount needed to fulfill the EU target from 2003 of 5.75% biofuel in year 2010. Today Brazil supply EU with ethanol made from sugar cane, and this import might increase in the future if the pace of construction within the sector does not increase.

The massive interest and funding for 2 Generation biofuels has resulted in generation of several pilot and demonstration projects within this field especially in USA. Using cost sharing as a model it has been possible to get a large number of 1 Generation bioethanol producers interested in investing in the upcoming field. In EU substantial funding for 2 Generation biofuels demonstration project is mainly a result of national funding and the current EU Research Program has not shown to be suited for this type of development demanding a substantial amount of funding- and much more focused as the typical EU project. A list of companies active within the 2 Generation bioethanol field is shown in table 1 along with a description of there upcoming demonstration projects.

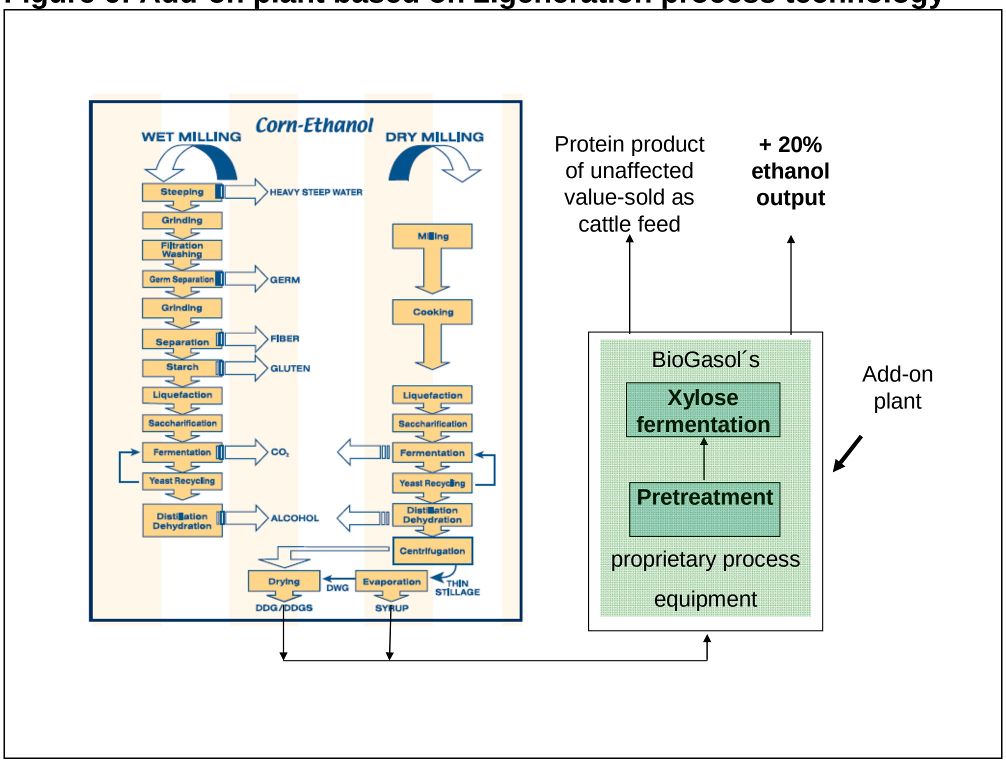
Table 2: Companies active within the 2 Generation

Company	2 Generation projects
Abengoa (Spain)	Abengoa is among the World's largest ethanol producers. During the summer of 2007 Abengoa will have a 2G demonstration plant in operation in Salamanca-Spain. The plant will on a daily basis convert 70 tonnes of agricultural residues (such as wheat straw) into ethanol. The plant will produce 5 mn liters of ethanol per year.
BioGasol (Denmark)	BioGasol opened its pilot plant in September 2006; the capacity of the fully integrated pilot plant is 16.400 liters of ethanol per year. BioGasol has started design of a 2 G demonstration plant with a capacity of 10 mn liters of ethanol per year. The complete plant will be in operation in April 2009.
Celunol (US)	In November 2006 Celunol put an ethanol plant in operation in Jennings. During the summer of 2007 a 2 G plant at the same site will produce 5.3 mn liters of ethanol per year. In January 2007 Celunol opened a small 2G pilot plant in Japan, producing 1.4 mn liters of ethanol per year based on wood residues.
Iogen (Canada)	Iogen has a 2G pilot plant. Iogen has plans for a full scale plant that will be in operation by the summer of 2007 producing 75.7 mn liters of ethanol per year.
Mascoma (US)	In the State of New York Mascoma plan to start construction of a pilot plant the summer with a yearly capacity of 1.9 mn liters of ethanol. The plan is to put the plant in operation late 2007/early 2008.
Poet Energy (US)	Poet Energy is among the World's largest ethanol producers and US´s second largest producer. Poet Energy plans to build a 2G plant in Iowa in 2009 with a capacity of 190 mn liters of ethanol per year. The plant will later be expanded to produce 473 mn liters of ethanol per year.
SunOpta (Canada)	Sunopta has developed a pre-treatment process. Together with GreenField the have plans for a 2G demonstration plant in Ontario or Qubec. Sunopta also has planer for a 2G demonstration plant in China in a corporation with China Resources Alcohol Corporation. This plant will be in operation late 2007 producing 6.4 mn liters of ethanol per year.
TMO (UK)	TMO has plans for 2G demonstration plant in Rotterdam, The Netherlands. The plant will be put in operation early 2008 producing about 12 mn liters of ethanol per year.
Xethanol (US)	Xethanol will build a 2 G demonstration plant in Augusta producing 189 mn liters of ethanol per year from the summer of 2007. Xethanol will also build a pilot plant in Bartow, Florida. The feed stock is residues from citrus production. The pilot plant will initially produce 0.2 mn liters of ethanol per year increasing to, 1.9 mn liters of ethanol ethanol a year after first production

6. BIOFUELS TECHNOLOGY

Bioehanol production by 1 Generation technology results in production of a feed product besides of bioethanol. In a dry mill approximately 1/3 of the raw material end up as feed, 1/3 ends up as bioethanol while the rest will end as carbon dioxide during the conversion process. The feed product is of relative low quality- it is composed of denaturized proteins, a low quality starch and some lignocellulose. Its value as a feed is mainly limited to cows and the price of the product is under pressure along with the increasing amounts being produced. The feed product might, however, be used a raw material for 2 Generation biofuels production resulting in a higher outcome of ethanol per ton of corn kernels. Integration of 1 and 2 Generation technology will therefore, be a promising way for adding 2 Generation bioethanol into a 1 Generation bioethanol plant (figure 6).

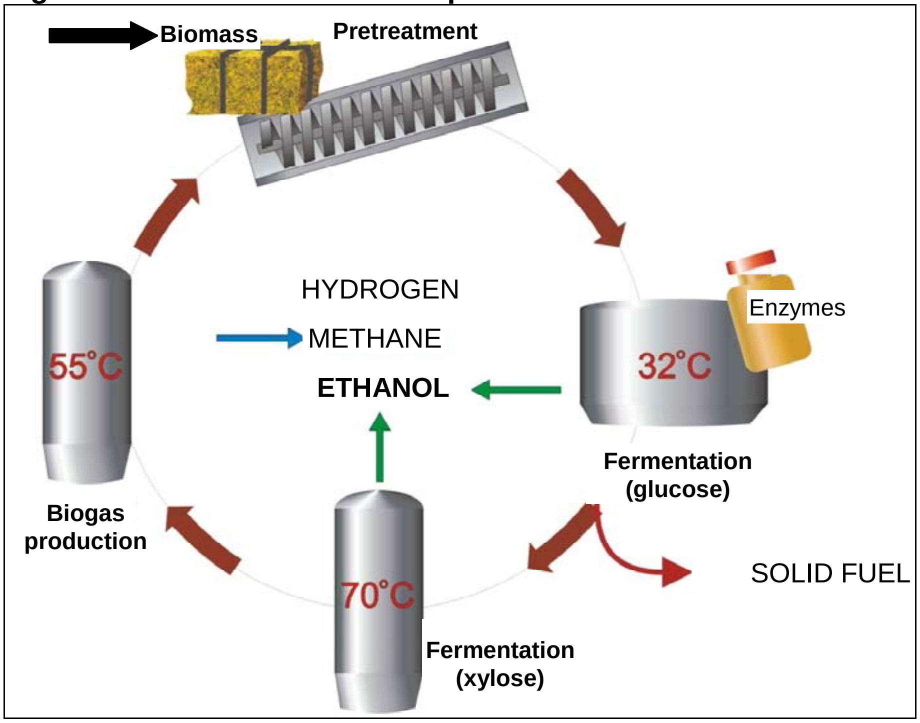
Figure 6: Add-on plant based on 2.generation process technology



The extra investment needed for using the feed fraction will have a low payback time and the new technology will be introduced using a rather easy-convertible raw material compared to for instance corn stovers, which can be gradually introduced after the new process is in function.

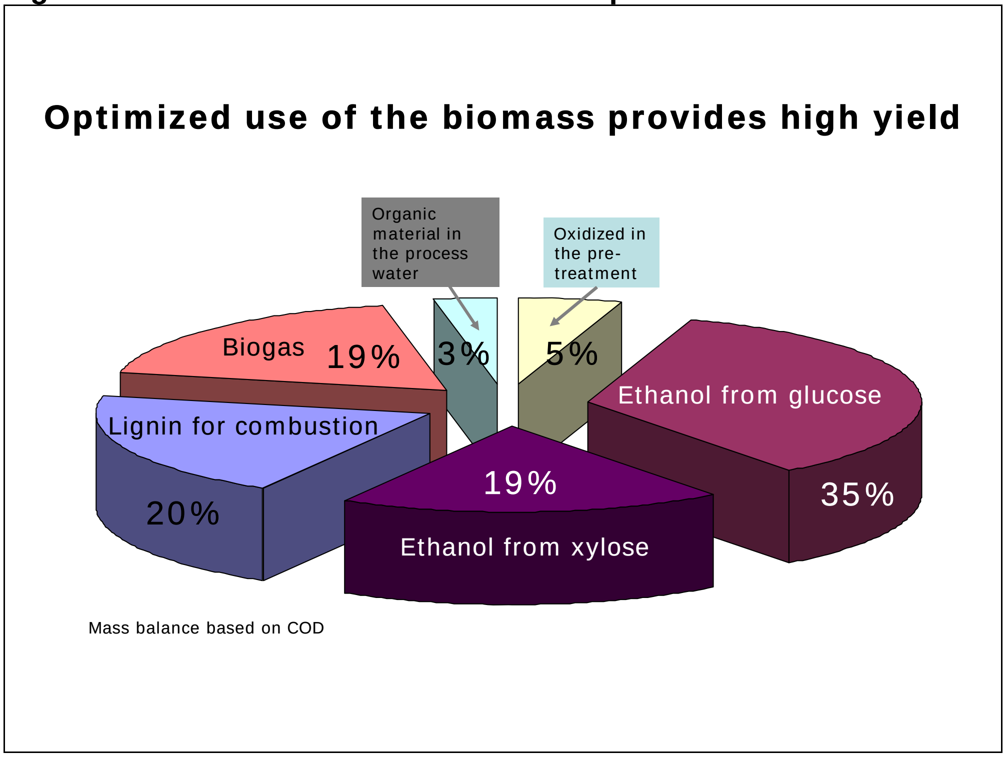
Sustainable 2 Generation biofuel production demands that more fuels or products than bioethanol is produced. Bioethanol can only be produced from carbohydrates meaning that 25-40 % of the raw material will be left as a waste if not used for other purposes. The MaxiFuels Concepts is constructed to maximize the outcome of energy products and making use of the whole biomass for production of energy products, figure 7.

Figure 7: The MaxiFuels Concept



In this concept a solid fuel (the lignin fraction), hydrogen and methane is produced in addition to ethanol. Water is further reused in the concept and nutrients are taken out as a fertilizer. By using all available carbon in the raw material the outcome will be a low-cost ethanol made by an environmentally secure method. Furthermore, the process has a high net energy conversion and is therefore an example of a type of process that should set the standards for the future production of 2 Generation biofuels.

Figure 8: Outcome of the MaxiFuels concept



7. CONCLUSION

The future is bright for 2 Generation. Substantial funding is necessary to bring this technology to the market and further to ensure that industries in EU can compete with US industries, which right now has major financial support. EU Research Programs needed to be more focused and to be better suited for supporting demonstration projects linked to specific member states.