INTERNATIONAL WORKSHOP ON DEFINING ISSUES IN BIOFUELS R&D

AUGUST 3-7, 2008
GRAND HOTEL SAN MICHELE
CETRARO (CALABRIA), ITALY

WORKSHOP SUMMARY AND RECOMMENDATIONS

May 2009

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6 METROTECH CENTER
Brooklyn, NY 11201
T: 1-718-260-3743 - F: 1-718-260-3754
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Above all, thanks to participants from 15 countries who freely exchanged their ideas in an informal atmosphere.

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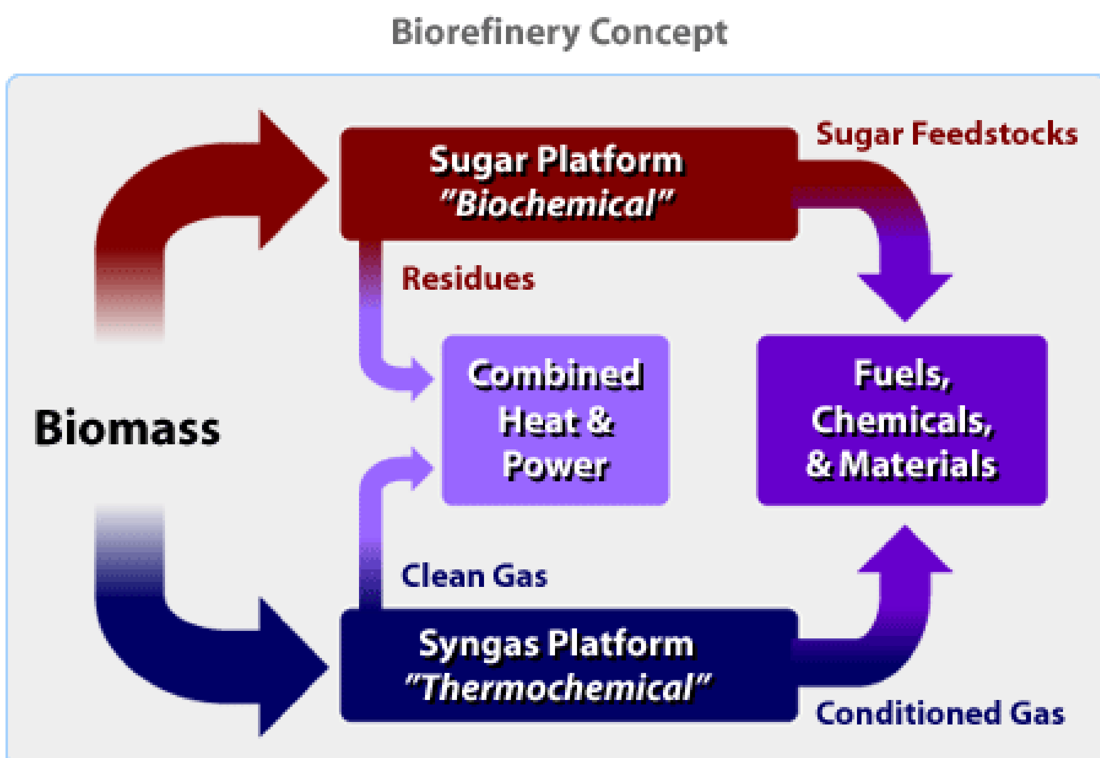
WORKSHOP SYNOPSIS

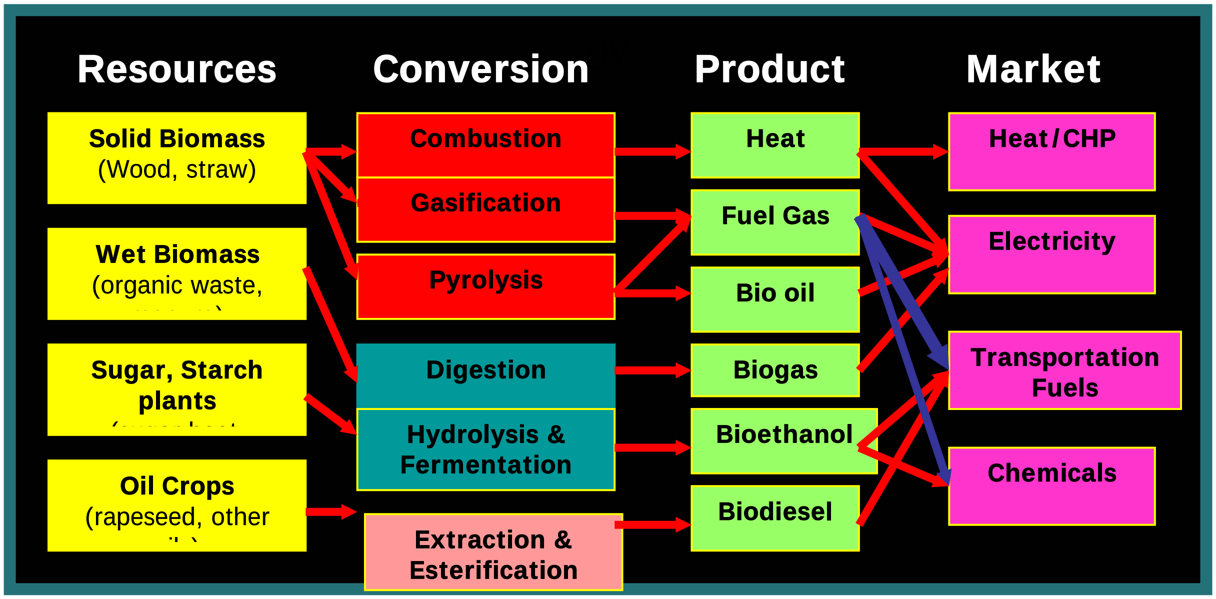
The switch to renewable energy picked up pace in the United States after methyl t-butyl ether (MTBE), a gasoline additive was banned. The commercial production of ethanol showed an enormous 300% increase between 2000 and 2007 to 6.485 billion gallons, though all came from fermentation of corn. As our global society grapples with the issue of CO_2 emissions from fossil fuels, alternate feedstocks must be considered. Though the potential of biomass energy derived from forest and agricultural residues worldwide is estimated at 30 EJ/yr, about 7% of the world's annual energy demand, the heterogeneity of biomass feedstock poses a challenge for processing to fuels products that typically leads to under utilization of the raw material. The recently released United Nations report "*Climate Change 2007: The Physical Science Basis*" is likely to give impetus to further boost the share of renewables for fuel production but R&D challenges remain to fully integrate feedstocks in the marketplace.

In August 2008, a workshop "International Workshop on Defining Issues in Biofuels R&D" was convened in an informal setting in Cetraro (Calabria), Italy. The workshop focused on sensible utilization of biomass that is typically categorized as four types: woody plants, herbaceous plants/grasses, aquatic plants, and manures. Biorefineries that have "Biochemical" (Sugar platform) and Thermochemical" (Syngas platform) as complementary routes to process biomass to fuels and chemicals (Figure 1) were the subject of discussion.



Source: National Renewable Energy Laboratory (NREL)

A better representation of the biorefinery can be seen in Figure 2 in which biomass is categorized into four types based on their processing option.



Source: Chemical Engineering, October 2006

Figure 2 also lays out known biomass processing options in column 2, corresponding products in column 3 and the markets penetration (Column 4) as these technologies enter the marketplace. Another topic sought to emphasize understanding of the net energy output of fuels from renewables and their potential benefit to society. The workshop sought to build upon previous workshops held around the globe. In 2007 alone, lead funding agencies in the United States sponsored workshops such as: 1) *"Breaking the Chemical and Engineering Barriers to Lignocellulosic Biofuels: A Workshop to Develop the Roadmap for Making Lignocellulosic Biofuels A Practical Reality"*, jointly sponsored by the National Science Foundation (NSF)/ United States Department of Energy (U.S. DOE)/ American Chemical Society (ACS), Washington, DC, June 25-26, 2007; 2) *"Navy Alternate Fuels Workshop- Minimizing the Impact on Navy and Marine Corps Operations"*, sponsored by the Office of Naval Research, Arlington, VA, June 27-28, 2007 dedicated to the sea-based needs, and 3) *Agriculture Research Service (ARS) Bioenergy- Customer/ Stakeholders Workshop*, sponsored by the United States Department of Agriculture (USDA), St. Louis, Missouri, September 18-19, 2007. During the workshop, the exchange of ideas among international participants helped to identify and reinforced science and technology issues that may lead to next-generation technologies of enhanced utilization of carbon in renewable feedstocks as biofuels for global use.

The workshop focused on identifying fundamental science issues in biofuels that are driven by in-use commercial technology knowledge base. The participants were divided in the following breakout sessions. Topic 1: Bio-Based Waste Processing Options; Topic 2: Crop Biomass Processing Options and Topic 3: Production and Storage of Fuels with Chemicals. The breakout session topics built upon the themes addressed by the featured speakers. The speakers list is included in Appendix II. The workshop agenda left enough time for informal interaction among participants (Appendix III).

This workshop included invited participants from 15 countries that geographically had representation from Europe, Asia, North America and South America. The event brought together researchers from academia, government laboratories, and industry to share their experience and thoughts to address biomass utilization issues that are considered crucial to develop next-generation technologies. The diverse views are evident from reports from the breakout sessions. However, some key issues are at the forefront as challenges. For example, a presentation from Imperial College described a study to understand the mechanisms regulating the plant cell wall composition and structure that will allow maximizing biocatalyzed conversion of carbon in biomass. A presentation from National Science Foundation outlined the roadmap for next-generation hydrocarbon biofuels production from lignocellulose grown with minimum land use change- the biofuels targeted are green gasoline, diesel, jet fuel, ethanol and butanol.

The Alberta Research Council presentation on their anaerobic digestion “Integrated Manure Utilization System” (IMUS) technology highlighted the versatility of the technology for converting variable feedstocks (i.e. food processing wastes, specified risk materials, rendering materials, and manure) to produce biogas and novel products for diversifying the agricultural industry. The value of one of their products, a nutrient-rich soil additive was emphasized as the point was made that nutrients taken from the soil need to be returned to the soil to ensure the sustainability of the agricultural industry.

Emission specifications for engines are becoming more stringent. The presentation from the (Canadian) National Research Council showed that bio-transportation fuels like biodiesel will need to meet the same quality specifications as petroleum-based transportation fuels for engines to pass performance tests. The costs for small producers to do the processing needed to meet the quality specifications will be prohibitive. An alternative approach was suggested by the presentation from Natural Resources Canada. The aim would be towards developing coprocessing schemes for bio-oils and petroleum crudes at refineries. Integration of bio-oils into conventional fuel streams would not only ensure that quality specifications are met but would also make use of the current infrastructure for distribution and sales.

A plenty of biomass is revitalizing the Korean effort to change its status from energy-importing to energy-independent nation. To become a nation with the sustainable growth, Korea has devoted its efforts to developing renewable energy, with a vision of “low-carbon and green growth.” Biofuels are a key alternative before ‘hydrogen-based economy’ will come in transportation. Biodiesel is the first biofuel to be commercialized in Korea, and efforts have been made to increase its usage. Bioethanol may present another option. To prepare for the future, biobutanol, biohydrogen and cellulosic ethanol are under consideration. A strong cooperation between the government, companies, and researchers is encouraged to achieve their goal.

Spain, as a member of the European Union (EU) and also a signatory of the Kyoto Protocol, developed a program: *Plan de Energías Renovables 2005-2010* that forms the basis of the national strategy for the promotion of renewable energies. The general objectives set in this plan include replacing 12 % primary energy, 30 % electricity and 6 % transportation fuels with renewable fuels. Despite significant progress, Spain is still far from meeting these objectives primarily due to slow growth in the demand for biofuels and the limited success of biomass fired power plants. The evolution in other technologies has been faster, situating Spain as world a leader in photovoltaic and wind energy. The overview at the end of this chapter provides a brief description of key projects and present activities in the area of biofuel production and biomass valorization.

As this report is being written, the funding agencies in the United States led by the United States Department of Energy (US DOE) alone have selected both the commercial sector as well as the research institutions for multiple awards totaling several billion dollars to develop efficient pathways to lignocellulosic conversion to biofuels. For example, a DOE target price of $1.01 per gallon must be achieved by 2012 for ethanol produced from feedstocks other than corn. .

This report should be viewed as a supplement to an extensive DOE/NSF/ACS report mentioned earlier in this summary. This report identifies R&D issues that will help develop highly efficient methods to process lignocellulosic materials to biofuels that can supplement petroleum-based fuels. It is hoped that this document will help funding agencies of the participating nations to consider selecting projects for international collaborations. Such collaborations will avoid data duplication and concentrate financial resources to advance the science for development of commercial technologies in the very near future.

Devinder Mahajan, Chair
Ponisseril Somasundaran, Co-Chair
Kyoung Ro, Co-Chair

REPORTS FROM BREAK-OUT SESSIONS

Report from Sessions 1 & 2

SESSION 1: BIO-BASED WASTES PROCESSING OPTION
SESSION 2: CROP-BASED BIOMASS PROCESSING OPTION

Session Leaders: Heather Dettman and Kyoung Ro

Session 1 and Session 2 were combined to get better synergy between the waste and biomass feedstock processing options. The participants discussed ideas in an informal atmosphere and their unedited comments were captured by the discussion leaders. Below is a summary of their comments as reported by the discussion leaders.

Discussion

Recommended principles for development of bio-based feedstocks:
Priority use of bio-products as food
Priority use of bio-energy is for food production energy needs/food production sustainability
Prime lands producing food and their waste go to bio-energy production
Marginal lands produce crops for bio-energy production
Processes profitable at all scales

List of feedstocks: manure, municipal waste (treated and untreated), municipal organic solid waste, plant waste, food processing waste (solid and liquid), food service waste, mischanthus, switchgrass, genetically modified crops, pulp and paper, packing plants, tree trimmings, dead livestock (mortality), jatropha, algae, sunflower seeds, any hydrocarbon that is not recognized as a transportation fuel, waste from bio-processes.

List of products generated: methane, liquid fuels, carbon/char, syn-gas, ethanol, hydrogen, electricity, heat, renewable (green) natural gas, scrubbers, green catalysts, bio-fertilizer, bio-diesel, bio-chemicals, coke, glycerin, bio-oil, bio-surfactant, bio-lubricant, ethers, rocket fuel, compost, bio-based materials, peat moss replacement (soil filler), bio-drilling fluids, waxes/solvents, bio-plastics, textile materials, paper, plywood, cement additives, soil conditioners, bio-pharmaceuticals

List of processes:
Anaerobic digestion

- dry fermentation
- nutrient recovery
- pathogen/pharmaceuticals/estrogens destruction

Subfractionation of feeds and products

- Characterization of green catalysts to enable emulsification of fuels

Carbonization

- improve yield

- create designer charcoal (high yield carbonization)
- ensure air and water quality control

Incineration/thermal combustion
- utilization of ash (fertilizer, cement encapsulation, metals extraction)
- air quality control

Delayed coking process

Optimal sequencing and integration of processes: maximizing use of all by-products
- Corn ethanol to distillers grains to anaerobic digestion to thermo-chemical conversion
- CO_2 capture/close the CO_2 loop
- Diversify products to maximize value and minimize waste.

Optimizing heat exchange processes
- All thermochemical processes
- Dewatering and drying processes

Developing cheap and robust green catalysts
- Wet gasification
- Down stream catalytic conversion processes (i.e. F-T processes)

Scalable processes
- Low pressure
- Farm scale gasifier/pyrolysis/carbonization
- Methods for densification and suitability for transport

Gasification
- Feedstock usage or combined with coal/petroleum products

Develop methods to measure the system techniques
- Methods to quantify "effects of doing nothing", i.e. measure environmental benefits
- Destroying pathogens

System for certification of processes

Multi feedstock (robust and flexible) processes
- Gasification that can accept multiple feedstocks to deal with moisture content, materials handling, sizing, gas ratios
- Anaerobic digestion/co-digestion

Carbon credit trading protocols – certification/validation
- Land application of biochar
- Quantification of methane emissions from livestock facilities

Improve processes to better utilize bio-fuels/bio-products/gas emissions
- Conversion of CO_2 emmissions to biomass (i.e. algae)
- Capture nutrients (i.e. nitrogen, phosphorous, potassium) in forms that can be concentrated and transported
- Capture toxins in a form that can be encapsulated/sequestered

Bio-engineering
- Metabolic engineering to optimize products/output
- Improve yield at lower temperatures
- Increase resistance to product (i.e. ethanol)
- Metagenomics on organisms for optimizing performance
- Optimize co-substrate utilization
- Bio-hydrogenation and biocracking of hydrocarbons/oxygen removal

- Enzyme engineering to enhance activities
- Genetic engineering to increase product yields
- Efficient innovative bio-scrubbing

Integrate with current industries/infrastructure

- Integration of multiple green energy sources (i.e. solar, wind, biomass)

New innovative ways of utilizing energy and products
Processes appropriate for agricultural systems functionality
Designer feed-stocks that meet the needs of natural microorganisms

Roadblocks:
Balance between food and fuel and bio-products
Profitability
Price stability on feedstock and products
Robustness
Social acceptance/Public and industry acceptance
Transportation
Efficient catalysts operating at low temperatures
Yield limitations
Selectivity
Soil health/crop rotation
Efficiency of conversion from solar energy to chemical energy
Water quality, availability
Funding sources
Government support/funding/legislation/regulation
Vulnerability/network stability
Human capital/training
Flexibility or adaptability to different feed-stocks to produce products as needed
Quality control
Optimizing land use for appropriate/sustainable crops
Communication chain from biomass producer to transportation to biomass conversion
Safety considerations regarding the processes
Cost of manufacturing at all scales/Economies at small scale
Fuel degradation during storage resulting in energy loss

Benefits of bio-based fuels and chemicals/products:
Setting up a system for evaluating credits for all natural resources (water, CO2, air, soil, etc)

- Environmental impact payments

Life cycle Analysis Considerations

1. Bio-based waste processing options
   - Use WASTE FIRST!!!!
   - Animal manure is a significant contributor (potentially) to renewable energy. However, the 10 M bbl crude oil (equivalent) per year is small when compared to the 20.7 M bbl per day oil consumption in the U.S.

- Therefore, it is much better to promote biochar or waste biofuel production in terms of its benefits to the agricultural sector and for its environmental benefits, rather as an energy resource (but should be considered on a specific location or case by case basis).
- The costs that were presented are the direct costs. These should be compared to the indirect benefits (water quality, NH_3 production, waste volume reduction, etc) to give a more realistic comparison, i.e. what are the indirect costs of not processing this waste?
- The simplicity of operation of biochar production is quickly lost if the desire is to produce chars with specific characteristics. As char properties become more specific, greater control of the process is required. Are these desired char properties compatible with farm-based systems, or does this imply a more centralized collection and processing arrangement?
- What are the break-even cost points for:
    - CO_2 credits
    - NH_3 production
    - Water quality
    - Energy production
    - i.e. what are the costs of these commodities/services that make them higher than can be produced with a farm-based system?
    - These costs (price) points are also important for the activated carbon products.
- Is there enough carbon to meet environmental remediation needs? If not, what is the fraction of the market that can be met with these materials?
- What is the potential transport radius that remains cost effective, balancing multiple processing plant capital costs vs. transportation costs? Are the "confined animal" feeding operations distributed spatially such that the central facility model is applicable nationally?

2. <u>Bio-based feedstocks – meeting requirements</u>

- Does it make more sense to modify the upstream infrastructure (create polymers, feedstock prep, etc) or the downstream infrastructure (distribution, engines, etc)?
- Farm-scale processing could be sized to produce bio-crude at a steady annual rate from a large seasonal feedstock supply.
- Infrastructure must include testing and measurement methods developed for petroleum-based fuels and products, pipeline and pump designs, engine designs, maintenance and service industries, etc, that have all been developed for petro-based fuels and products.
- Do we have a clear understanding of what the infrastructures currently are and how they might need to change to accommodate biofuels?
- How will upstream infrastructure changes impact environment? What are the changes in effluents? Are there increased needs for special methods for catalysts? Will these systems require increased processing energy?

Report from Session 3

PRODUCTION AND STORAGE OF FUELS AND CHEMICALS

Session Leaders: Ayusman Sen and Charles (Andy) Miller

Session 3 focused on biomass utilization issues, i.e., on market- and infrastructure-driven products. As in Sessions 1 and 2, the participants discussed ideas in an informal atmosphere and their unedited comments were captured by the discussion leaders. Below is a summary of the participant comments as reported by the discussion leaders.

Discussion

Key Concepts

- Focus on Products
  - What products are needed?

- Develop Toolboxes
  - Process components
  - Fundamental methods and measurements
  - Models and assessment protocol for storage capability

- Ensure Infrastructure Flexibility
  - Move toward sustainability
  - Accommodate local feedstocks

- Work within Constraints
  - Existing infrastructure, environmental protection, costs

Products

- "Currently, best replacement for hydrocarbons is hydrocarbons"
- Prefer to produce what is needed rather to make users modify their needs
- Implies move toward "renewable gasoline," "renewable diesel," "renewable jet fuel," etc.

Toolboxes – Process Needs

- Gasification/Fischer-Tropsch: process intensification (scale down)
- Pyrolysis: catalysis, stabilization of pyrolysis oils
- Aqueous phase refining: scale up

- Aqueous phase catalysis: stabilization, characterization
- Synthetic and systemic biology
- Lignocellulosic materials: deconstruction
- Algae: production and down-stream processing
- Single molecule fuels: DME, biobutanol, DMTHF

Toolboxes

- Go beyond "biochemical" and "thermochemical" labels:
  - Hybrid systems – catalytic, biocatalytic, photobioreactors, in combination

- Syngas fermentation
- Cellulosic biocatalytic hydrolysis, catalytic refining
- Hydrogen from solar energy
- Fundamental measurements and methods needed to optimize process development
  - Which processes have the best thermodynamics and kinetics?

Constraints

- Must work with existing infrastructure (transport, engines, etc.)
- Maximize net energy output
- Maximize sustainability:
  - Atom economy
  - Minimal inflows (especially water)
  - Minimize other effluents, residues that need disposal or processing
  - Minimize life cycle greenhouse gas emissions

Icing on the Cake

- Coordinate interface between energy and agriculture?
  - Use of biochar residue as soil amendment
  - (Multi)Farm-scale reactor operation
  - Need for steady refinery inputs vs. seasonal agricultural production

- Flexible design of plants/processes to accommodate future changes

APPENDICES

APPENDIX I

LIST OF ABSTRACTS

LIVESTOCK WASTES PROCESSING OPTIONS

Authors: Kyoung S. Ro, Keri B. Cantrell, and Patrick G. Hunt
Affiliation: USDA-ARS Coastal Plains Soil, Water & Plant Research Center
Florence, SC, USA
E-mail: kyoung@ars.usda.gov

Abstract

According to the recent study jointly sponsored by the USDA and US DOE, U.S. agricultural lands currently have 35 million dry tons of available, sustainable animal manure. Assuming an average high heat value of about 13.4 MJ $kgTS^{-1}$ for various animal manures, an efficiency of 15% for extracting useful energy, and an energy value of about $100 per barrel of oil equivalent, this sustainable animal manure would provide energy with an approximate worth of one billion US dollars per year. In this breakout session presentation, two thermo-chemical processing options are introduced to extract bioenergy from wastes especially from livestock wastes; wet gasification and carbonization.

Wet gasifying or catalytic hydrothermal processing swine manure would produce energy comparable to combusting the same amount of brown coal. The costs of a conceptual first generation wet gasification manure management system for a model swine farm were found to be significantly higher than that of traditional anaerobic lagoon systems. However, there are many significant environmental advantages of the wet gasification that have not yet assigned monetary values: 1) removing oxygen demanding wastes, estrogens, and odorous compounds; 2) achieving total pathogen kills; 3) recovering most of nitrogen as ammonia, which could be used as a fertilizer; and 4) producing relatively clean water that, after minimal treatment, could be recycled as a livestock drinking water. One of the biggest challenges for this processing option is development of robust, cost- effective catalysts.

Carbonizing dry livestock wastes such as poultry litter would produce valuable solid product--bio-char. Bio-char can be used as a cooking fuel, feedstock to existing coal firing power plants, and converted into a value-added activated carbon. Bio-char can also be used as a soil amendment to improve soil fertility. Preliminary bio-char soil application research results showed that bio-char improved soil quality, reduced leaching of nutrients, and increased soil organic carbon. In addition, the fixed carbon of the bio-char is quite recalcitrant and may be qualified for future carbon credit, which would bring additional revenue to farmers. For the carbonization process, developing energy efficient, air pollution free, and high yield carbonizing processes to generate bio-char with tailored qualities ("designer charcoal") is the major engineering challenge.

SYNTHESIS OF BIODIESEL FROM WINERY WASTE

Carmen María Fernández
Affiliation: Institute for Chemical and Enviromental Technology
E-mail: carmenm.fmarchante@uclm.es

Abstract

This study was conducted in response to the energy needs that currently exist. The fossil sources (petroleum, coal and natural gas) are limited and polluting. Moreover, the new regulation in the reform of Common Organization of Market (OCM) of wine eliminates the subsidy to distillation in 2013. Therefore, the wineries will have the problem of waste management.

The aim of this work was the treatment of that waste as fuel for its revaluation. First, the grape seed was obtained from the washed and separated waste. Secondy, the grape seed was pressed or extracted with solvent in order to produce oil. Finally, the oil obtained was used to synthesize biodiesel. The yield of the grape seed oil was about 18.5 wt % of grape seed. The proportion of grape seed was approximately 0,020 kg per kg of grapes. Therefore 15,000 tons of grape seed oil per year could be obtained in Castilla-La Mancha (Spain).

The transesterification process has been carried out satisfactory by a conventional process. The composition of grape seed biodiesel was very similar to a conventional sunflower biodiesel. Some properties of grape seed biodiesel were: the cold filter plugging point (CFPP) was -7 ºC; the iodine value was 138; the cetane number was 48. In order to improve the critic grape seed biodiesel properties, this was mixed with one of good quality, high oleic sunflower whose production was fomented by Communitarian Agrarian Policy (PAC) in Spain.The properties of mixed biodiesel were -6.2ºC for CFPP and 109.2 for iodine value and 52 for cetane number. These features were appropriated and allow to use this biodiesel as biofuel.

BIOFUEL PRODUCTION FROM BIOMASS-DERIVED VOLATILE FATTY ACID PLATFORM

Author: Ho Nam Chang
Affiliation: Dept of Chemical and Biomolecular Engineering, KAIST
E-mail: hnchang@kaist.edu

Abstract

The typical biorefinery platforms are sugar, thermochemical (syngas), carbon-rich chains, and biogas platform. The sugar platform uses hexose and pentose sugars extracted or converted from plant body. The thermochemical (syngas) platform is chemical or biological conversion process using pyrolysis or gasification of plant to produce biofuels. The carbon-rich chains platform is used to produce biodiesel from long-chain fatty acids or glycerides. Those platforms have unique advantages and disadvantages. Our group has concentrated on the biogas platform producing methane gas from municipal solid wastes through anaerobic digestion (AD) processs, which is composed of rapid acidogenesis and slow methanogenesis. This acidogenic and methanogenic process is widely used for biogas production from the treatment of wetted waste materials (foodwastes, sludge, and manure) in the worldwide. The volatile fatty acids (VFAs) are short-chain fatty acids composed of mainly acetate and butyrate, and easily produced from non-woody biomass with low lignin content in acidogenesis step by the natural consortia of mixed anaerobic bacteria. And then it is slowly converted to biogas (methane, CO2) by methanogenic bacteria naturally.

Now, we would like to suggest a new platform using VFAs for biofuel and biochemicals production, because the VFAs can be produced from a cost-effective way using AD process that does not need sterilization, additional hydrolysis enzymes (cellulase and xylanase) and high cost pretreatment step in case of low-lignin content biomass. Considering that raw material alone constitutes 60-80% of biofuel production costs, biofuels made from the VFAs derived from the waste organic biomass can have a potential of economical advantage. A problem is how to convert VFAs to biofuels and biochemicals. In the presentation, we will give possible solutions in order to produce bioethanol, biobutanol, biodiesel, and biohydrogen as well as biogas through biological or chemical processes. And we will introduce our ongoing researches related with the VFA platform.

HIGH-PERFORMANCE LIQUID HYDROCARBON FUELS FROM LIGNIN

Author: Wlodzimierz W. Zmierczak
Affiliation: University of Utah, College of Mines and Earth Sciences
E-mail: W.Zmierczak@utah.edu

Abstract

Lignin is second only to cellulose as the most plentiful, renewable and energy-rich carbon source on earth. Its content in lignocellulosic biomass is in the range of 15 to 30 wt%. Currently a limited supply of separated lignin is produced mostly as a by-product of the pulp and paper industry. However, in the near future, a considerable amount of lignin will be available from lignocellulosic biomass-to-ethanol and other biorefineries as a residual material, with limited opportunities for its utilization. Chemically, lignin is an amorphous three-dimensional energy-rich phenolic biopolymer, the structure of which is composed primarily of phenylpropanoid building units, i.e., (a) p-hydroxyphenylpropane, (b) guaiacylpropane, and (c) syringylpropane, interconnected by etheric and carbon-to-carbon linkages. It is the biomass component with the highest energy content. Due to its low oxygen content, the lignin represents 30 to 45 wt% of the total energy of the lignocellulosic biomass and, because of its molecular nature, can be converted (depolymerized and hydroprocessed) directly to a variety of liquid hydrocarbon fuels. Numerous previous efforts on lignin conversion, which were essentially limited to single-stage processing methods, including hydrocracking, cracking, hydrogenation, hydrotreating, liquefaction in hydrogen-donor solvents, etc., did not generate an economically viable technology. Recently, the University of Utah developed an efficient multi-stage lignin-to-fuels technology which is designed to convert lignin feedstocks mostly to alkylated benzenes, alkylated bicyclic aromatics, and their hydrogenation products. This product composition constitutes high-performance blending components required for production of a high-octane gasoline, and jet and rocket fuels. Products from the lignin-to-fuels process technology can easily meet the U.S. government energy policy goals to develop alternatives to petroleum products without negative effects on the food market. These include bio-rocket, bio-jet, and bio-gasoline fuels. In the framework of this policy goal, consideration has been given to production and utilization of a new class of naphthenic kerosenes, which can fuel the next generation of aircraft, rockets, and second generation reusable launch vehicles. The utilization of the new kerosenes is an important part of the technology development programs initiated by the NASA Space Launch Initiative and JANNAF Interagency Propulsion Committee. Also, DARPA initiated a program for the development of a new class of low-cost biomass-derived hydrocarbon compositions, possessing properties similar or superior to those of current JP-8 jet propellant.

YEAST ACTIVITY MANAGEMENT TO INTENSIFY THE ETHANOL PRODUCTION IN A MEMBRANE TWO STAGE BIOREACTOR

Author: Sanchez-Gonzalez Y.
Affiliation: National institute of Sciences Applied. LISBP
E-mail: yuriana@insa-toulouse.fr

Abstract

The ability to produce ethanol from low-cost biomass will be key to making ethanol competitive with gasoline. In order to increase the ethanol productivity efficiently, it is necessary to increase the biomass concentration and more precisely the viable cell concentration. An original two-stage bioreactor with cell recycle (BBRC) was developed; it is composed by two nonequal-volume reactors with a internal cell recycling loop. The first reactor (R1), dedicated to the growth reaction, was fed by all the nutrients (substrates, salts and vitamins). The second reactor was coupled to an ultrafiltration membrane in order to reach high cell concentration and/or high ethanol concentration. The originality of our configuration is the partial recycling of the cells between the two stages of the pilot ; this "regeneration" loop should increase the yeast tolerance towards ethanol, allowing the cells to transfer from a medium with high concentrations in biomass and/or ethanol (R2) to a medium with a weak concentration in ethanol (R1) The aim of this study is to mimic the internal regeneration loop of the BBRC in order to characterize and quantify the microbial behaviour (kinetics, viability, by-products…) in various media with different ethanol concentrations to improve the microbial activity in the BBRC. The impact of the initial ethanol concentration on the dynamic behaviour of S. cerevisiae was studied through the determination of the fermentation kinetics (growth, ethanol and by-product productions), the cell viability and the yeast tolerance to ethanol in the different conditions.

SYNTHETIC MICROBIAL ECOSYSTEMS FOR BIOFUEL PRODUCTION

Author: Cynthia H. Collins
Affiliation: Rensselaer Polytechnic Institute
E-mail: ccollins@rpi.edu

Abstract

Microbes are currently being used to produce many valuable chemical compounds relevant to biotechnology, industry and medicine. Most of these processes utilize a single microbe to produce the desired product. However, the production (or degradation) of chemicals requiring the expression of many enzymes can lead to a large metabolic burden upon the organism, leading to suboptimal yields. As desired chemical processes become increasingly complex, employing multispecies cultures will both decrease the strain on a given organism and add additional levels of control. Naturally occurring microbial communities are composed of many species, each playing a specific role within the community. We are building synthetic microbial ecosystems wherein different chemical reactions are allocated to each microorganism. Synthetic biology aims to construct organisms with designed functions using naturally occurring component parts. This work has largely focused on engineering genetic regulatory networks with specific behaviors. Recent efforts have been made to extend these engineered networks to multicellular behaviors, in essence engineering simple communities. As a first step towards engineering microbial communities that carry out novel processes, such as biofuel production, we are developing high-throughput methods for identifying conditions under which the constituents of a community will coexist, without the addition of expensive chemicals such as antibiotics. We have focused on the role of resource competition under nutrient poor conditions and have found that the ratio of two bacterial species, Escherichia coli and Salmonella typhimurium, in a liquid co-culture can be varied through the addition of very inexpensive chemicals. Libraries of transcriptional reporters for each of the species have been employed to assess changes in gene expression under conditions that lead to differing community compositions. Analyzing changes to the transcriptome of each organism provides insight into how changes to the environment that affect community composition affect the physiology of each microorganism. As the individual components of the community are engineered to carry out specific tasks, our understanding of the physiological and transcriptional states of the microorganisms will guide our implementation of synthetic genetic networks for optimal enzyme production and community composition and stability. We are currently building on this preliminary work with the goad of engineering synthetic bacterial communities for the conversion of biomass to biofuels.

TRANSESTERIFICATION OF CORN OIL USING HETEROGENEOUS CATALYSTS

Authors: Carmen María Fernández[a], Rubi Romero[b*], Maria Jesus Ramos[a], Ángel Perez[a], Sandra Luz Martínez[b], Pedro Jimenez[b]
Affiliation: [a]Departamento de Ingeniería Química, Facultad de Ciencias Químicas, Universidad de Castilla La Mancha, Avenida Camilo José Cela s/n 13071 Ciudad Real. Spain.
[b]Facultad de Química, Universidad Autónoma del Estado de México, Paseo Colón esq. Paseo Tollocan s/n 50120 Toluca, Estado de México, México. *email: rrr@uaemex.mx
E-mail: Carmenm.fmarchante@uclm.es

Abstract

Introduction: Biodiesel is obtained by the transesterification of triglyceride oil. These triglycerides are converted to the respective alkyl ester and glycerol by transesterification with short chain alcohols, typically methanol. The transesterification of vegetable oils constitutes an efficient method that provides a fuel (biodiesel) with chemical properties close to the mineral diesel fuel. In this work, the influence of particle size on the ester formation during the transesterification of corn oil has been studied.

Experimental method:
Preparation of catalysts: Zeolite X agglomerated with bentonite (35:65, zeolite:bentonite) was used. After grinding and sieving, particles with an average particle size of 1.4, 2.1 and 7.2mm were obtained. Finally, the bound material was air-calcined at 550 °C for 15 h. To improve their basic properties, the catalysts were impregnated with an aqueous sodium acetate solution. The metal concentration was calculated to yield a nominal loading of 4.2% Na. The catalysts were then dried and heated at a rate of 1 °C/min to 500 °C and held at that temperature for 4 h to form the occluded sodium oxide species in the cages of the zeolite.
Transesterification reaction: the corn oil transesterification process was carried out in a 500 ml continuously stirred spherical reactor coupled to a condensation system. Experimental conditions were as follows: reaction time, 7 h at atmospheric pressure; weight of catalyst, 10 wt % of initial oil weight; molar ratio of methanol:oil, 6:1; reaction temperature 60 ºC and stirring rate, 600 rpm. After reaction time, the reaction was stopped and the mixture was centrifuged to remove both glycerol and the catalyst.

Results and discussion
Table 1 shows the influence of size particle in the transesterification reaction of corn oil using heterogeneous catalysts. As it can be seen, the use of catalysts with less size of particle can improve the yield of methyl ester in the transesterification reaction of corn oil. Besides, the sample with particle size of 1.4 mm makes the methyl ester content very close to the European Standard EN 14214.

Table 1. Effect of particle size on the properties of biodiesel

Catalyst	Methyl Ester content (%w/w)	Viscosity at 40 °C (mm^2/s)	Acid value (mg KOH/g)	Water content (mg/kg)
EN14214	> 96.5	< 5	< 0.5	< 500
NaXB4.2(*1.4)	90.6	5.8	0.1085	100.1
NaXB4.2(*2.1)	88.5	8.9	0.1380	107.8
NaXB4.2(*7.2)	85.8	9.7	0.1120	105.4

*Particle size (mm)

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WHITE BIOTECHNOLOGY FOR BIOFUELS AND BIOKEROSENES :A ROAD MAP

Author: Gérard GOMA,Carole JOUVE -MOLINA
Affiliation: INSA Toulouse
E-mail: goma@insa-toulouse.fr

Abstract

World needs bio fuels and to reduce CO2 emission: it is evidence. Ecological engineering is also necessary Howether,it is not sufficient to built strategies on:" it is accepted, ,it is said,,," now we need to progress on proof.: decision and opinion makers have to prove what they are saying. We need to argue against the people who develop the syndrome Banana (Built Absolutely Nothing near Anyone Near Anyway). As the world energy consumption is 10. 3 Giga Teps /y (2005) and the world agro production 5.5 Giga tons /y, it reasonable to say –with strongest arguments –that the biomass contribution to the energy can reach more than 25% of the total consumption in the years 2025/2030. For us it is a limit and we consider that this contribution is realistic and necessary. It is a goal where we can have synergies between food and non food utilisation of agro productions. Biomass to liquid fuel by white bio technology way is a challenging task at the frontier where merge green, blue, red and white biotechnologies. We consider the 12 principles of the green chemistry as a basic rule. As the economy of bio fuels (and energy) is difficult, the bottlenecks to solve remains: 1°the raw material is the entire plant: carbohydrate reserve, lingo cellulosic materials both 2° production of very cheap fermentescibles carbon sources in the frame of a clean factory 3° uses of all biodegradable carbon sources by the mean of micro organisms considered as "cells factories». That mean that if we have an input of various and cyclic maters there is several potentials outputs both in" bulk "strategy (bio fuels ,animal feed,,,,)and" speciality" strategy 4° need a clear strategy combining process and product engineering. The aim of our contribution is to demonstrate that bio diesel from carbohydrate is a new route which can enhance the bio diesel production from agro production. We describe results of yields, productivities, concentration profiles for the mains agro substrates and strains lipid producers. An interesting point is the similarity of lipid production by yeasts and oleo proteaginous plants. The modern tools box of white biotechnologies adapted to the four bottlenecks given previously describe the road map of a promising route for bio fuels, bio kerosene and diesel production. It is the road map for bio fuels of third generation

CONVERSION OF BIOMASS TO LIQUID FUELS AND CHEMICALS

Author: Ayusman Sen
Affiliation: Pennsylvania State University
E-mail: asen@psu.edu

Abstract

The production of liquid fuels and chemicals directly from biomass is of great current interest, given the diminishing reserves of fossil fuels such as coal, oil, and natural gas-the current commercial sources of fuels and chemicals. Biomass is the only practical source of renewable liquid fuel. Further, the use of biomass substantially reduces net carbon dioxide emission because the latter is recycled in the biomass regeneration. We will present several strategies for the catalytic conversion of biomass to liquid fuels and chemicals. These include methanol production from biomass-derived syngas, the direct conversion of biomass to liquid fuels for transportation, and the conversion of carbohydrates to alpha,omega-diols which are important polymer intermediates. We will also discuss new chemistry that must be developed to achieve these conversions on a practical scale.

WOOD BASED BIOETHANOL PRODUCTION, PRETREATMENT

Author: Kando K. Janga
Affiliation: Department of Chemical Engineering, Norwegian University of Science and Technology (NTNU)
E-mail: kando.janga@chemeng.ntnu.no

Abstract

In the mission to tackle the challenge of high cost of production of fuel ethanol from lignocellulosic biomass, the Nordic Energy Research has proposed a whole value chain process evaluation approach in a project attempting to produce cost-effective fuel-ethanol from the Nordic countries' abundant and reliable source of forest reserves. Nordic forestry resources amount to approximately 60 million m3 which can theoretically be converted to 10,000 million litres of bioethanol (approx. 80% of annual gasoline consumption). The heterogeneous, complex cell wall structure and recalcitrant nature of lignocellulosic substrates impacts the whole production process from the front end pre-treatment to hydrolysis and fermentation. The development of a novel cost-competitive conversion process of the Nordic wood to fuel ethanol is set through a basic understanding of the physical and chemical mechanisms and process improvements in the pre-treatment step. Furthermore, there is a need for identification and deployment of robust and thermophilic enzymes in the hydrolysis of wood carbohydrates, as well as selective and effective fermentative microorganisms for conversion of monosaccharides into bioethanol. Finally, modelling and simulation is a valuable tool in finding optimal process configurations. In accomplishment of these goals, the project participants in the Nordic countries include Paper and Fibre Research Institute, Norway (project owner and coordinator), SINTEF (Norway), STFI-Packforsk (Sweden), Matis ohf – Prokaria (Iceland), VTT (Finland), Novozyme (Denmark) in the Research and development part together with industrial partners Borregaard, StatoilHydro, Norske Skog, Norwegian forest owners (Norway), SEKAB (Sweden), and Novozymes (Denmark). The poster will give a presentation of the project and the main challenges which are addressed by the project partners.

NOVEL SYNERGISTIC BIOSURFACTANT SYSTEMS FOR GREENER BIOFUELS

P. Somasundaran, J. W. Lee, R. Gross, C. Lo and J. Wu

Langmuir Center for Colloids and Interfaces, NSF Industry/university Cooperative Center for Surfactants, Columbia University, New York. Chemical Engineering Department, The City College of New York, New York and Polytechnic University of New York

Abstract

The increasing requirements for environmental protection and escalating demands from the general public have made "going green" inevitable for all industries. In this regard, biosurfactants play a duel role. They are indeed biodegradable; in addition, when used alone or under synergistic conditions in combination with the conventional surface active agents, they can be used for <u>reducing the dosage requirements and thus the resultant carbon foot print</u>. In our work, we are exploring the performance of next generation greener and more efficient surface-active agents in industrial applications such as enhanced oil recovery, methane hydrate processing as well as oil transport and remediation of associated effluent. Our overall aim is to deliver a framework of knowledge of the criteria and colloidal and nanostructural properties of selected "Greener" model surfactant systems including sugar based alkyl glucosides, sophorolipids., which have been found to exhibit unique properties compared with conventional reagents. For instance, alkyl maltosides as well as sophorolipids produced by the yeast Candida bombicola were found to adsorb well on alumina but not on silica. More importantly, mixed with other surfactants they showed synergism/antagonism, which can be used to tune the performance of the systems. Polysaccharides and modified polysaccharides also showed special colloidal properties that can potentially be used for oil extraction, transportation as emulsions of hydrocarbon based compounds etc. These exploratory studies show nature as a potential source for benign reagents with unique properties for producing greener fuels

BIOFUELS CHARACTERISTICS FOR COMBUSTION

Author: Mr. W. Stuart Neill
Affiliation: National Research Council Canada
E-mail: stuart.neill@nrc-cnrc.gc.ca

Abstract

In North America, renewable fuel content regulations are being adopted for gasoline and diesel fuels to increase energy independence and to reduce greenhouse gas emissions. Biofuel blends appear to perform satisfactorily in current technology internal combustion engines under most conditions when the blending concentration is small. Two of the biodiesel challenges encountered to date are characterization of biodiesel blends and successful demonstration of biodiesel usage under the range of Canadian climatic conditions. On the other hand, very little consideration has been given to how biofuel blends will perform in advanced combustion technology engines that are being developed by engine manufacturers to meet increasingly stringent vehicle emission regulations.

Experimental combustion and emissions data will be presented with biodiesel blends operated in conventional diesel and homogeneous charge compression ignition (HCCI) engines. HCCI is one example of a range of advanced combustion technologies currently being developed for both spark ignition (gasoline) and compression ignition (diesel) engines. The data shows that the biodiesel blends have a modest impact on the conventional diesel combustion process, primarily in modifying the well-known trade-off between particulate matter (PM) and oxides of nitrogen (NOx) emissions. In an HCCI engine, however, the higher latent heat of vaporization of biodiesel and its different fuel chemistry compared to ultra-low sulfur diesel fuel significantly impact HCCI combustion performance and emissions.

The authors conclude that if advanced technology diesel engines are to operate effectively with a wide range of fuel options in the future, then more knowledge about fuel property and chemistry effects on advanced combustion strategies is badly needed. This research is required today to ensure that fuel blends of the future, which will include more and more unconventional components, function in future engines. More specifically, it would be beneficial for biofuel producers to better understand evolving fuel end-use trends so they can minimize the cost of producing fuel blending components that meet the requirements of both current and next-generation engine technologies.

HYDROGEN PRODUCTION FROM BIOMASS IN A CONICAL SPOUTED BED GASIFIER

Author: Martin Olazar
Affiliation: University of the Basque Country
E-mail: martin.olazar@ehu.es

Abstract

Hydrogen is an important raw material widely used in the chemical industry. Moreover, it is considered to be a clean alternative to fossil fuels provided that it is produced from renewable sources like biomass. The low cost of the raw material and its environmental advantages, such as its low nitrogen and sulphur content and zero CO2 emissions, make gasification of biomass a sustainable process for obtaining hydrogen. Steam has been used as gasification agent because the main objective of this study is to maximize hydrogen yield. Nevertheless, the amount of tar formed during the steam gasification reaction is higher than that obtained using air, and therefore catalytic tar reforming is required.

The steam gasification of pinewood pellets (6 x 10 mm) has been carried out in a gasification pilot plant provided with a conical spouted bed reactor. The effect of temperature over the gasification process has been studied in the 800-900 ºC range. The bed was initially made up of 30 g of sand, and a water flowrate of 1.4 ml/min has been used to spout the bed. It has been verified that, using this water flowrate, gas velocity is approximately 1.2 times minimum spouting, as required for ensuring a suitable gas-solid contact. The ratio between biomass and water was maintained at 1:1 in all the runs.

The products obtained in the gasification have been classified into three different fractions: gas, tar (containing benzene and compounds of higher molecular weight) and char. The gas yield at 800 ºC is low, but an increase of 100 ºC raises the gas amount to 47.2 % (wt) and reduces the tar amount to 43.5 % (wt). Temperature also has a positive effect on the amount of hydrogen in the product gas, leading to a concentration of 45 % (vol) at 900ºC. Methane and carbon monoxide decrease and carbon dioxide concentration slightly increases by increasing temperature.

The tar fraction has been characterized and the compounds have been divided into four different lumps: heterocyclic, aromatics, light polyaromatics and heavy polyaromatics. The tar is made up mainly of light polyaromatic compounds, with naphthalene being the main product. The composition of the tar is also affected by temperature; significant deoxygenation is observed when the gasification is carried out at 900 ºC.

Finally, char yield decreases from 14 to 9% in the 800 to 900 ºC temperature range. It should be taken into account that the char yield depends on the residence time in the reactor, and in our case the char is removed from the bed by means of an outlet pipe so its residence time is shorter than two minutes.

GASIFICATION OF WASTE BIOMASS FOR THE COMBINED PRODUCTION OF ENERGY AND ADSORBENT MATERIALS

Author: Guillermo San Miguel
Affiliation: ETSII, Departamento de Ingeniería Química y Medio Ambiente, Universidad Politécnica de Madrid
E-mail: g.sanmiguel@upm.es

Abstract

The conclusion reached by most experts working in the field of energy valorisation of biomass is that pyrolysis and gasification technologies are technically feasible but economically unfavourable (Manahan et al., 2007). Although things appear to be changing rapidly, primarily due to the high price of fossil fuels, commercial gasification plants still need to be heavily subsidized in order to be competitive. To reverse this situation, one of the options involves using gasification not only with the aim of producing energy but also as a waste management alternative. Hence, the economic success of the technology would not depend solely on the quality of the resulting products (mainly combustible gases) but also on the ability of the process to deal with a residue that would otherwise need to be incinerated or disposed of at a cost (e.g. dried sewage sludge, paper black liquor, agricultural by-products, used tyres, etc). Furthermore, the same gasification reaction that is employed for the energy valorisation of biomass is also commercially used for the production of activated carbons (San Miguel et al., 2003; 2006). If the process is intended for energy valorisation, the gasification reaction is conducted with the purpose of achieving high reaction rates (high temperatures and heat transfer conditions in fluidised bed reactor) and complete oxidation of the carbonised biomass. Based on these considerations, an alternative approach that will be discussed in our presentation involves conducting the gasification of biomass residues with the combined objective of producing not only combustible gases but also a carbonised fraction that could be commercialised for its textural and adsorption properties. The extent of the gasification reaction and the conditions under which the process is performed (temperature, atmospheric conditions, particle size, reactor design) need to be adjusted depending on the nature of the biomass and the propertie s intended for the resulting carbon. With a bulk market value of 1,000-10,000 US$/ton, the economics of biomass gasification could be greatly favoured if the process was aimed at producing both fuel gas and adsorbents. Our presentation will describe the potential of different biomass residues for being used as a base material for active carbon production, it will discuss the conditions under which these materials could be gasified for the combined production of both energy and adsorbents, and how all these parameters could affect the overall economic performance of a biomass gasification plant.

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BIOMASS PYROLYTIC LIGNIN CHARACTERIZATION WITH HPLC

Author: Martin Olazar
Affiliation: University of the Basque Country
E-mail: martin.olazar@ehu.es

Abstract

In view of declining petroleum resources, combined with increasing demand by emerging economies, the biofuels obtained from the flash pyrolysis of biomass could become a sustainable source of fuel. However, in order to consolidate pyrolysis oil in the market, studies on its composition and aging are essential. GC analysis can detect only about 40 wt% of conventional pyrolysis oil. Complementary analysis techniques are therefore necessary [1]. Bio-oil contains polar, non-volatile compounds that are accessible only by HPLC or GPC analysis [2]. In this sense, the aim of this work is to optimize an analytical method to identify and characterize the pyrolytic lignin contained in the liquid from the flash pyrolysis of biomass. Two samples understood to have a high composition of pyrolytic lignin have been studied: a solid residue that appears in the condenser during the flash pyrolysis of sawdust at 450ºC (sample 1) and a solid residue precipitated during the catalytic upgrading of the light pyrolysis oil in a fluidized bed reactor (sample 2). Pyrolysis reactions have been carried out in a pilot plant provided with a conical spouted bed reactor. Samples were characterized using an Agilent HPLC 1100. Due to the chemical properties of the samples, Reversed Phase Liquid Chromatography (RPLC) is recommended, and so Atlantis T3 column (Waters) was chosen for analytical RPLC. Water (H2O) and acetonitrile (ACN) were selected as solvents and samples were diluted in THF (2.5% w/w). A method based on 0-100% ACN/H2O gradient elution for 60 min at 202 nm wavelength was carried out for both samples. Using the same method, chromatograms of pyrolysis light liquid and a commercial lignin (organosolv lignin) were also obtained. Certain peaks appear in the same range in the four chromatograms, which are those representative of lignin. In addition, using gel permeation chromatography (GPC) the average molecular weight of the samples was determined. A TSK-GEL Alpha-3000 column was used and the flow rate was 1 ml/min of THF (202 nm). Using RPLC, the peaks corresponding to pyrolytic lignin have been identified in the chromatogram of light oil obtained by flash pyrolysis of sawdust and, consequently, a large scale separation process of this undesired compound may be developed under this strategy. In addition, the average molecular weights were determined by GPC, with the results being similar to those in the literature [1].

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FROM ANIMAL MANURE TO VALUE-ADDED PRODUCTS – OPPORTUNITIES FOR AGRICULTURAL INDUSTRY

Author: Xiaomei Li
Affiliation: Alberta Research Council
E-mail: xiaomei@arc.ab.ca

Abstract

As the livestock industry expands in North America, proper management and utilization of large quantities of manure generated at beef, dairy, swine, and poultry operations presents both challenges and opportunities. Currently the industry commonly employs the manure management practice of land application for its fertilizer value. This often leads to over-application of manure on adjacent land. Social and environmental objections to over-application of manure on land include odour, pathogens and excess nutrients. Prolonged over-application of manure leads to accumulation of soil nutrients to excessively high levels and, as a result, may cause contamination of both surface and ground water supplies. Emissions of methane, nitrous oxide and carbon dioxide as greenhouse gases also cause concerns. The area of land required for manure application increases with increasing size of livestock operations. As a consequence, transportation of the manure over longer distances becomes inevitable as livestock operations intensify, increasing greenhouse gas emissions and adding to the cost of operation. In the meantime, to reduce nutrient accumulation, confined feeding operations are required to land-apply nutrients at levels that match crop requirements. A considerably large land-base is required to achieve this "dilution", and as distance between the sites of manure concentration and application increases, costs of disposal rise. Much of this cost of transport arises from the fact that manure is bulky, heavy with high moisture content, and low in nutrient concentration. Novel, cost-effective technologies that promote the utilization of energy and plant nutritional values of manure while minimize negative environmental impacts and mitigate greenhouse gas emissions are needed. In the meantime, a global movement to produce renewable energy in the form of biogas, biodiesel and ethanol is gathering momentum. Government policies are promoting renewable energy production and use to sustain the environment, continue economic growth and reduce dependency on non-renewable fossil fuels. Particularly from the waste to energy is an attractive and popular strategy for many levels of governments. This provides a great opportunity for agriculture and livestock sectors addressing their environmental challenges. Biogas technology can turn animal manure and other organic wastes into renewable energy and minimize the environmental footprints for many sectors. At the same time biogas production can be combined with new technological developments to turn manure and related wastes into biofertilizers or other value-added products and recycled water. Furthermore, biogas technology can be a central link to other bioprocesses, such as biofuel production. This presentation will highlight current activities in Alberta, Canada that helps the livestock industry to fully utilize this technology platform that turns management of animal waste and other organic wastes from a problem into new economic opportunities.

GREEN FUEL

Author: G. Santhosh Kumar
Affiliation: MVGR College of Engineering
E-mail: ssaanntthhoo@yahoo.co.in

Abstract

This paper describes a new system using fossil fuel and sustainable energy to produce methanol with CO2 zero emission. In this system, the heat to maintain the reactions is supplied from the sustainable energy such as hydraulic, solar, or wind-generated power. Therefore, this process can be named a new green-fuel production technology. The objectives of this paper are to introduce the practical process of the new system with C02 zero emission. Preheating technology of coal-water mixture (CWM) is the core technology to realize the process, because sustainable energy is used for vaporization of water and to decrease oxygen consumption in the gasifier. Water in the CWM was continuously vaporized with a preheated and steam and dry coal fine particles were atomized in a tube and fed to the pressure vessel or the combustion chamber. The internal auto-thermal steam reforming of methane is also the core technology to avoid CO2 emission. The new reactor consists of packed layers with oxidation and reforming catalysts wherein methanol is produced by simultaneous coal gasification and steam reforming of natural gas. Production cost of methanol has been estimated as Rs. 13.29/kg or less in a case. This is nearly the same as that for the commercial methanol production process, when the CO2 recovery and disposal process is taken in.

KEYWORDS: C.W.M, methanol, gasification, natural gas, steam reforming.

CONVERSION OF BIOMASS TO LIQUID FUELS AND CHEMICALS

Author: Ayusman Sen
Affiliation: Pennsylvania State University
E-mail: asen@psu.edu

Abstract

The production of liquid fuels and chemicals directly from biomass is of great current interest, given the diminishing reserves of fossil fuels such as coal, oil, and natural gas-the current commercial sources of fuels and chemicals. Biomass is the only practical source of renewable liquid fuel. Further, the use of biomass substantially reduces net carbon dioxide emission because the latter is recycled in the biomass regeneration. We will present several strategies for the catalytic conversion of biomass to liquid fuels and chemicals. These include methanol production from biomass-derived syngas, the direct conversion of biomass to liquid fuels for transportation, and the conversion of carbohydrates to alpha,omega-diols which are important polymer intermediates. We will also discuss new chemistry that must be developed to achieve these conversions on a practical scale.

BIOFUELS RESEARCH NEEDS: AN EPA R&D PERSPECTIVE

C. Andrew Miller
U.S. Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory

Abstract

The U.S. Environmental Protection Agency (EPA) is developing an agency-wide strategy for addressing the environmental impacts of large-scale biofuel production and use. EPA's Office of Research and Development (ORD) is the lead organization for development of the strategy, which incorporates needs and actions from across EPA's regulatory, regional, and research components. From ORD's perspective, the impacts of biofuels must address three key factors, each of which poses significant research needs. First, the impacts of biofuel production and use must be considered across the entire biofuel supply chain – from feedstock production and transport to fuel conversion, distribution and storage, and end use. Second, the increased production and use of biofuels will impact the broader agricultural and energy systems, through changes in commodity availability and price. Finally, it is crucial to ensure sustainable biofuel production and use, to protect the biological capacity of feedstock production as well as to prevent damage to other ecosystems. Research issues that emerge from this strategy include how to quantify and prevent excessive nutrient runoff during feedstock production, prevention of and response to biofuel leaks from fuel storage tanks, measurement of vehicle emissions when using different biofuel/gasoline blends under a range of environmental conditions, evaluation of life-cycle greenhouse gas emissions that incorporates the full supply chain, and a need to understand how energy and agricultural market systems interact.

RATIONALE FOR DEVELOPMENT OF BORON NANOPARTICLES FUEL ENHANCEMENT

Dr. Richard Coffin
Code 6114
Naval Research Laboratory
Washington, DC
richard.coffin@nrl.navy.mil

Abstract

The US DON is reaching a stage in international energy availability that needs changes for secure support of strategic planning. Potential future energy includes biofuels, synthetic fuel designs, hydrogen and fuel cell application. While these fuels can contribute to the energy demands in the private and industrial markets, there are several short comings in support of military fuel requirements. First, biofuels typically have lower energy than the current JP-5, 7, and 8 and there is a high cost in the production. A reduction of energy in fuels will result in shorter distance and lighter loadings during performance in tactical missions. In addition, during long term storage biofuels are microbial degraded, resulting in changes in the energy content. For other technology development energy and hydrogen and fuel cells do not support the general military need in armored vehicles, ships, and aircraft. Development of synthetic fuel production does not guarantee to maintain the future global energy demand. With development of more energy dense fuels, there is potential to increase the payload, range, and/or performance of our air, land and sea tactical systems. To date new hydrocarbon fuels (e.g. JP-10) have volumetric energy densities only ~15% above that for JP-8 (34.2 MJ/liter), and further significant increases are unlikely for synthetically feasible liquid hydrocarbons.

Other elements such as aluminum, boron and iron have a greater energy potential than carbon based fuels. Boron additives were first tested in rocket fuel development in the 1950's and found to have a large potential energy contribution, but were unstable during ignition. Recent development in nanotechnology has shown the capability to stabilize the energy in boron for application in fuel enhancements with coatings that prohibit oxidation and control the combustion. Boron is one of the few potential additive materials that also increase gravimetric energy density, relative to the best hydrocarbon fuels. Boron has a higher energy density (135.8 vs. 129.4 MJ/liter), and is affordable as B_4C, due to commercial application as an abrasive. The novel features of in the use of nano-scale particles, coating the particles with a catalyst to enhance combustion of the hydrocarbon carrier fuel, coating the hybrid fuel/catalyst particles with an organic layer to prevent premature oxidation and render the particles fuel-soluble, and optimization of the hydrocarbon fuel to maximize combustion efficiency for the particles, provides potential for a new step in fuel supporting Navy strategic missions.

Key performance metrics of a propulsion system include: (a) volumetric heat release (or thrust to weight ratio), (b) NO and other pollutant emissions, and (c) pressure oscillations or combustion dynamics. By increasing thrust to weight, the size of the propulsion system can be reduced or the range of the propulsion device can be increased (engine can go a longer distance

for the same amount of fuel). This can be of significant cost-savings benefit in air-breathing propulsion applications, for example, in ram-jet missile systems or gas-turbine military engines. Catalytically coated metal nano-particles offer several benefits: they can be dispersed over a wide volumetric region; they can significantly enhance the surface area of heterogeneously initiated combustion; they can be delivered to regions of interest through suitable aerodynamics, and the higher temperatures associated with catalyst-enhanced hydrocarbon combustion can efficiently burn boron or metal nano-particles adding more energy in the combustion system. Catalytic nano-particles can therefore potentially benefit current work in the area of air-breathing propulsion systems (e.g., gas turbine combustors, after-burners, Pulsed Detonation Engines, Ram-jet-missiles etc.), where rapid initiation of combustion and increase in volumetric heat release is desirable.

Our current project is designed to provide greater enthalpy in tactical fuels than currently available in carbon based sources. NRL Code 6114, in collaboration with scientists from GE, Naval Academy, Universities of Utah, Hawaii and Louisiana State, have joined with an overall objective of integrated technology development and testing program for increasing the range of vehicles for tactical missions via boron nano-particles mixed with hydrocarbon fuels. The initial focus area is examining the energy available in boron supplemented fuel and testing for possible changes in tracking signatures, wear on the engine, level of increased energy and fuel production costs. Development of alternate fuel will provide a focus for subsequent application to land, ocean and air gas turbine craft.

TRANESTERIFICATION OF NON-EDIBLE OILS TO BIODIESEL

Author: Poonam Singh nee' Nigam and Mrinal N. Kumar
Affiliation: Faculty of Life and Health Sciences, University of Ulster, Coleraine, Northern Ireland, U.K
E-mail: p.singh@ulster.ac.uk

Abstract

Due to global energy crisis and high prices of fuel, there is a renewed current interest worldwide in the use of agricultural materials as the resource for fuel production. But a lot of concern has been shown that this will be at the expense of food production, or will inflate food prices. The use of inedible crops, or their by-products, produced on land which cannot be used for conventional food crops would seem to be the solution, provided these crops can be used for power generation. Biodiesel is produced from vegetable oils using an esterification process which removes compounds that could harm a standard diesel engine. When the esterification is carried out by conventional methods, such as alkaline catalysts, biodiesel was found to be more expensive than petroleum-based diesel. This is mainly due to the high price of vegetable oil (which could be used for food), incomplete conversion and the need to remove non-reusable catalysts and by-products like soap. This project covers the identification of suitable non-food crops and their growth regions; a conventional chemical process to convert their oisl to biodiesel in an environmentally friendly, low cost manner; and a comparison of the technical and commercial properties of bio-diesels with petro-diesel.

CONVERSION OF ANIMAL MANURE TO CHARS AND THEIR USE AS ADSORBENTS FOR SELECT METAL IONS

Author: Isabel Lima
Affiliation: USDA-ARS-SRRC
E-mail: isabel.lima@ars.usda.gov

Abstract

Water quality and public health impacts of animal manure produced at large concentrated animal facilities prompted the need for viable solutions for their conversion and reuse. Our laboratory at the Southern Regional Research Center has shown that it is feasible to convert animal manure into granular activated carbons used for heavy metals remediation. Pyrolytic products or chars are low porosity, lower surface area materials that are intermediate products in the development of activated carbons. Both possess excellent adsorption properties, particularly with respect to the uptake of metal ions. Toxic metals contamination of various water sources is a significant problem in many parts of the United States. Chars, which can be produced from a number of precursor materials including coal, wood and agricultural plant wastes, have not been examined for remediation of this problem. Chars were produced by pyrolyzing a pelletized sample of animal manure (sourced from poultry, dairy cow and swine) under nitrogen at 700°C and 800°C for 1 hour. Specific physical and adsorptive properties for the resulting chars were determined and compared to chars made from wood, coal and coconut shells. Char yields decreased with pyrolysis temperature and were highest for dairy manure and lowest for swine manure-based chars with poultry chars in the middle, and ranged between 37 to 48% and 30 to 37%, for 700 °C and 800°C pyrolysis, respectively. Surface areas ranged between 92 and 318 m2/g, and were highest for the poultry manure based chars. As far as the char's ability to adsorb metal ions, best performing chars in order of adsorption efficiency were broiler manure char, turkey manure char, swine char and dairy char, with respectively 0.96, 0.62, 0.28 and 0.17 mmoles/g of Cu2+ adsorbed. Additionally, animal manure-based chars exhibited metal ion adsorption that far exceeded that of the reference chars, made from coal, wood or coconut shells, with neg ligent to no adsorption observed, under the same conditions. The conversion of readily available and renewable animal manures into chars for wastewater remediation might be an alternative to a disposal problem and at the same time create new markets for animal manures.

FROM LIQUID BIOMASS WASTE TO TRANSPORTATION FUELS

Author: Heather D. Dettman
Affiliation: Natural Resources Canada, CanmetENERGY
E-mail: Heather.Dettman@nrcan-rncan.gc.ca

Abstract

Current production of petroleum crudes for conversion into transportation fuels is measured in units of "millions of barrels" per day. As oil yield from biomass roughly correlates as "a ton of biomass to produce one barrel of oil", the proportion of bio-based feedstock being used in the total transportation fuel mix in Canada, and North America, will likely remain small. Over the last 100 years, the petroleum industry has setup a complex system for transportation fuel delivery including discovery and production of new petroleum sources, and efficient transportation of feedstock and products. As well, they have developed chemical and catalytic support industries to address flow-assurance issues during production, thermal conversion issues for meeting legislated product quality specifications, and corrosion and fouling issues throughout the entire "value-added" chain.

Petroleum crudes are not "all the same". Crudes from different sources have very different hydrocarbon structural characteristics in terms of their contents of hydrocarbon species [aromatics, naphthenes (cycloalkanes), and paraffins (alkanes)], contents of heteroatoms including sulphur, nitrogen, and oxygen (i.e. up to 5 wt % sulphur, 1 wt % nitrogen and 1 wt% oxygen), and contents of molecular species with different boiling point ranges (i.e. between 5 and 60 wt % of species with boiling point temperatures greater than 524°C (975°F). During production of transportation fuels, refiners use a variety of distillation, thermal processing (with and without hydrogen), and blending steps to meet legislated quality specifications related to engine performance.

Production of transportation fuels from bio-based feeds could be greatly assisted by integration with the petroleum industry. Since petroleum refineries understand how to produce transportation fuels, why not let them do it? Networks could be setup to transport bio-oil products to a local refinery where the bio-oil could then be used as blending stock and co-processed with petroleum feeds. Instead of having to meet final product quality specifications, bio-oil producers could aim for "minimum quality" specifications of refinery feeds. Utilization of oils generated from biomass waste streams could help meet the "continuity of feedstock" need of refinery operations. Integration of bio-oil feed at this stage of the value chain would take advantage of the existing infrastructure for processing and transportation fuel product distribution, result in one product for consumers, and would ensure that the quality specifications of the final fuels would be met.

UNDERSTANDING THE MECHANISMS REGULATING PLANT CELL WALL COMPOSITION AND STRUCTURE

Author: Thorsten Hamann
Affiliation: Imperial College London
E-mail: thamann@imperial.ac.uk

Abstract

Plant biomass derives mainly from plant cell walls. It represents an environmentally friendly and sustainable source of raw materials that can be used for production of fine chemicals, building materials, clothing and energy. However cell walls also represent a corner stone of the mechanisms plants have evolved to deal with biotic and abiotic stress or to generate the necessary mechanical support for growth. Thus there was an enormous selection pressure on plants to make the walls as sturdy and resilient to chemical or enzymatic breakdown by invading pathogens as possible. This is exactly the opposite of what "we" want because inaccessible walls are more difficult to process and to generate the products of interest to us. Because of the diverse industrial applications, researchers have been working on plant cell walls for a long time. Amongst the results of this work is an impressive knowledge (e.g. a parts list) of the components that can be found in cell walls.

However our understanding of the mechanisms regulating cell wall structure and composition is rather limited. The reasons being that cell walls are dynamic structures that vary between cells (e.g. large variability within an organism) and the diagnostic tools available to analyse cell wall processes were rather limited in the past. During the last couple of years this has changed with the arrival of new technologies and the establishment of model systems (e.g. green test tubes) like *Arabidopsis thaliana* that permit hypothesis driven science in a reasonably short period of time (mere months) and are also sufficiently small so large numbers can be grown in a confined space. This presentation will provide an overview of our knowledge deriving from different model systems regarding the mechanisms regulating cell wall structure and composition.

SYNTHESIS AND CHARACTERIZATION OF SILICA ENCAPSULATED MONO- and BI-METALLIC NANOCATALYSTS AND THEIR POTENTIAL IN STEAM REFORMING REACTIONS

Author: Debasish Kuila
Affiliation: North Carolina A & T State University, Greensboro, NC 27411
E-mail: dkuila@ncat.edu

Abstract

The first part of this presentation will focus on the synthesis of sol-gel coated nano-scale non-noble Co and Ni catalyst for hydrogen production from steam reforming of methanol (SRM) in Si-microreactors. The fundamental parameters involved in SRM such as nanocatalyst's activity, stability, and hydrogen production have been investigated. Silica support with porous structure show high surface area: ~ 450 m^2/gm for Ni/SiO_2 and ~.340 m^2/gm for Co/SiO_2. TEM images show the size of the catalyst particles to be ~ 10 nm in the sol-gel structure. The DTA and XRD results show that ~ 450 °C is the optimum temperature for calcination at which most of the metal hydroxides are converted to metal oxides without remarkable particle aggregation to form larger crystallites. The magnetization results indicate that ~ 33% cobalt oxide and ~ 45% nickel oxide were reduced to pure metals during hydrogenation at 450 ºC for 5 hrs; however, ~ 90% of Co and ~ 85% of Ni become inactive after the steam reforming reaction for 10 hrs. The steam reforming results showed 53% methanol conversion and 74% hydrogen selectivity at 5 μl/min and 200 °C for Ni/SiO_2 catalyst, which are higher than that for Co/SiO_2 catalyst. Both methanol conversion and hydrogen selectivity decrease with increase of the flow rates of reactants.

In order to improve the stability and surface area of the catalysts and their activities, we have developed one-pot synthesis of bimetallic nanocatalysts in mesoporous silica. Especially, we are interested to know the effect of noble-metal Pd on CO production during SRM and steam reforming of ethanol, bioethanol, etc to produce H_2. The novel materials in nanoporous silica were synthesized using cetyltrimethylammonium bromide (CTAB) as the surfactant. The synthesized materials are calcined at 480°C to remove the CTAB surfactant. The surface area of the novel materials increased significantly, ~ 900-1100 m^2/gm. The reduced Pd-Co alloy in the mesostructured material is prepared by reducing it with 4% hydrogen at high temperature. The novel silica materials containing Pd-Co alloy have been further characterized using high resolution transmission electron microscopy (HRTEM), X-ray diffraction (XRD), FTIR, SEM, BET surface area and magnetic measurements. The analysis of data reveals the presence of uniform bimetallic nanoparticles inside the silica nanopores with superior magnetic properties. The reduced novel bimetallic materials are currently being tested to study their potential for hydrogen production by methanol steam reforming in a quartz glass reactor. We expect these materials to be excellent candidates for production of H_2 from bioethanol and other biofuels.

SUBMITTED ABSTRACTS
AUTHORS NOT IN ATTENDANCE

TOWARDS EFFICIENT UTILIZATION OF XYLOSE

Author: Zhanglin Lin
Affiliation: Department of Chemical Engineering, Tsinghua University
E-mail: zhanglinlin@mail.tsinghua.edu.cn

Abstract

Efficient utilization of C5 sugars in particular xylose remains a bottleneck issue in biomass-based production of chemicals and fuels. We have sought to address the utilization of xylose by targeting key enzymes and regulatory factors. A new variant of xylose reductase that prefers the coenzyme NADH instead of NADPH was obtained through three rounds of saturation mutagenesis of selected sites, the ratio of kcat/Km with respect to NADH/NADPH was improved by a factor of 13 to favor NADH (Microbial Cell Factories 6:36 (2007)). Additional changes to other limited sites have yielded further improvements. The performance of these mutants in fermentation is under evaluation. Also, a transporter was engineered to relieve the catabolite repression effect mediated by glucose. Towards this end, a high throughput assay was developed to allow for quick identification of transport variants less inhibited by glucose. A number of such variants are being evaluated. A combination of imp roved transport and metabolism mechanisms should help better utilization of a C5 sugar like xylose.

RECOVERY OF CELLULASES BY ADSORPTION/DESORPTION USING CATION EXCHANGE RESINS

Author: Wu Jinchuan
Affiliation: Institute of Chemical & Engineering Sciences
E-mail: wu_jinchuan@ices.a-star.edu.sg

Abstract

Cellulases from *Trichoderma reesei* were recovered by adsorption in sodium acetate buffer at lower pHs using cation exchange resins followed by desorption in the same type of buffer at higher pHs. The weakly acidic ion exchange resin WK10 was found to be the best among the 7 resins tested in terms of the enzyme activity recovery. The optimal pH values for the adsorption and desorption were 4.0 and 8.0, respectively, and the optimal adsorption and desorption times were both 5 h. Almost 100% of the initial cellulase activity was recovered under the optimal conditions with the supplement of beta-glucosidase, which was unable to be efficiently recovered due to its strong adsorption (95.7%) but poor desorption (1.9%).

BIOFUELS: THE INDIAN SCENE

Author: k.s.murty
Affiliation: none
E-mail: murtysk1931@yahoo.co.in

Abstract

Coal has been the main source of energy in India and accounted for about 67 per cent of the commercial needs. The importance of increasing the use of renewable energy was recognized as far back as the seventies and the policy laid down covered sources such as biogas, biomass, solar energy, wind energy, small hydropower and such other emerging technologies. . India can be said to be a pioneer of biogas technology. The consumption of petrol and diesel products touched 114 million tonnes at an exorbitant expense of 80,000 crores (crore=100 million) and of this 112 million tonnes go to the transport sector alone. Research into biofuels started in the country in the eighties itself at the Indian Institute of Technology, with difrerent species of forest trees like mahua (*madhuca indica*)and neem (*azadichta indica*). The Indian Institute of Science, Bangalore started work with karanj (*pargania pinnata*), while the Central Salt and Marine Chemical Researh Institute. Bhavanagar initiated work on jatropa/ratnajot (*jatropa curcua*) and jajoba (*simmondesia chinensis*). Indian scientists have finalized a list of more than 100 plants suitable for biodiesel extraction. The government of India has made it mandatory to mix upto 10 per cent ethanol with petrol from October 2008 onwards, which would reduce considerably the consumption of petrol and thus the foreign exchange component. However, there is genuine apprehension that diversion of sugarcane, maize and corn and such other edible crops could affect food production. Thus, food security and biosecurity can be endangered and may put the country in the same situation as in the early sixties when food had to be imported under PL 480 from the USA. There also seems to be criticism all over the world in this regard and a five-year freeze on biofuels has been advised. In India, it is necessary to put a break on automobile production, which was encouraged twenty years ago leading to an increased use of oil ad its products.

The consequences of that step are there to see now. Improvement in the public transport system is badly needed in the country and it may help in reducing the consumption of petrol and other products. In the long run, biofuels could, without affecting the food security may solve the problem and further research is absolutely necessary.

BIODIESEL IN PAKISTAN

Author: Engr Naseer Ahmed Khan
Affiliation: N-W.F.P University Of Engineering & Technology Peshawar
E-mail: naseerahmedkhan2003@hotmail.com

Abstract

Pakistan like other developing countries needs continuous supply of cheap energy. It is common fear in today's world that fossil fuels will be depilated soon. The cost of energy is increasing continuously and is expected to be at its peak by 2050. Many technological advance countries are successfully using renewable energy sources for their energy needs, however, they still believe in the importance of fossil fuel. In renewable energy field, Pakistan is using hydropower for energy needs successfully, whereas, project regarding solar and wind energy are in progress. Biomass, a renewable energy source, is gaining interest of many researchers in world because it produces similar type of fuel extracted from crude oil, Energy from biomasses only depends upon the availability of cheap raw material source. Biodiesel, which is produced by the reaction of vegetable oil and alcohol, can be used with same or with better performance in diesel engine. It is clean fuel that causes less environment pollution as compared to petro-diesel. High cost and non continuous supply of vegetable oil is the main hurdle for its general acceptance. Many advance countries have developed strategy for continuous supply of cheap price energy crops (source of Biomass). Biodiesel is only the possible reciprocal to petro-diesel or otherwise diesel engine will be useless after depletion of crude oil. In this study biodiesel as energy source has been discuss which is indigenous diesel engine fuel and is beneficial for our environment, economy, and more importantly will increase the earning of our farmers.

APPENDIX II

WORKSHOP AGENDA

INTERNATIONAL WORKSHOP ON DEFINING ISSUES IN BIOFUELS R&D

AUGUST 3-7, 2008
GRAND HOTEL SAN MICHELE
CETRARO (CALABRIA), ITALY

ORGANIZING COMMITTEE

Devinder Mahajan, Chair (DMAHAJAN@BNL.GOV); Ponisseril Somasundaran, Co-Chair; (PS24@COLUMBIA.EDU); Kyoung Ro, Co-Chair (KYOUNG.RO@ARS.USDA.GOV); Duane Abata (*USA*); Joe D. Allison (*USA*); Richard B. Coffin (*USA*); Yunchul Chung (*SOUTH KOREA*); Heather D. Dettman (*CANADA*); Guillermo San Miguel (*SPAIN*); Gerfried Jungmeier (*AUSTRIA*); Dr. Luis J. Paz (*PERU*); Volkhard Scholz (*GERMANY*)

WORKSHOP AGENDA

SUNDAY (August 3)	
5:30 pm - 7:30 pm	Registration
7:30 pm - 9:30 pm	**Mixer and Dinner**
8:30 pm - 9:30 pm	Organizing Committee Meeting

MONDAY (August 4)	
8:00 am - 9:00 am	Breakfast
9:00 am – 12:40 pm	**Welcome** Devinder Mahajan, P. Somasundaran, Kyoung Ro **Keynote Lecture** **Dr. Pedro Gamio Aita** Vice Minister of Energy, Ministry of Energy and Mines, Lima, PERU Title: *TBA*
	Plenary Lectures I
	Session Chair: P. Somasundaran **Dr. Emiliano Maletta**, CIEMAT, Spanish Ministry of Education and Science, *SPAIN* *"Energy Crops"* **Dr. Thorsten Hamann**, Imperial College, *U.K.* *"Understanding the mechanisms regulating plant cell wall*

	composition and structure"
10:30 am - 11:00 am	Coffee Break
	Dr. Richard Coffin, Naval Research Laboratory, Washington, DC, *USA* "*Logistic Fuel Development: Nanoparticle Enhancement of Energy Density and Combustion Energy*"
	Dr. C. Andrew Miller, U.S. Environmental Protection Agency, *USA* *"Biofuels Research Needs: An EPA R&D Perspective"*
	Dr. Patrick hunt, United States Department of Agriculture (USDA)-ARS, Florence, *USA* **"***Energy from Livestock Manures***"**
1:00 pm - 2:00 pm	Lunch
2:00 pm -4:00 pm	***Ad hoc* sessions / Free time**
4:00 pm -7:00 pm	**Plenary Lectures II**
	Session Chair: Kyoung Ro
	Dr. John R. Regalbuto, National Science Foundation, Washington, DC *USA* *"Next Generation Hydrocarbon Biofuels"*
	Dr. Duane Abata, South Dakota School of Mining & Technology, *USA* *"NSF Center for Bioenergy Research and Development (NSF-CBRD)"*
4:45 pm – 5:15 pm	Coffee Break
	Dr. P. Somasundaran, Columbia University, *USA* *"Novel Synergistic Biosurfactant Systems for Greener Biofuels"*
	Dr. Ayusman Sen, Pennsylvania State University, *USA* *"Conversion of Biomass to Liquid Fuels and Chemicals"*
7:30 pm - 9:00pm	Dinner
9:00 pm – 10:00pm	Social Hour

TUESDAY (August 5)

8:00 am - 9:00 am	Breakfast
9:00 am -12:30 pm	**Plenary Lectures-III**
	Session Chair: H. Dettman
	Mr. Stuart Neill, National Research Council**,** Ottawa, *CANADA* *"Biofuels Characteristics for Combustion"*

	Dr. Byoung-In Sang, Korea Institute of Science and Technology, *SOUTH KOREA* *"Biofuel Research Activities in Korea"*
	Dr. Matt C. Smith, United States Department of Agriculture (USDA)-ARS, Beltsville, *USA* *"Biogas from Agriculture"*
10:45 am - 11:15 am	Coffee Break
	Dr. Guillermo San Miguel, ETSII, Universidad Politécnica de Madrid, *SPAIN* *"Gasification of Biomass Wastes for Combined Production of Energy and Adsorbents"*
	Dr. Xiaomei Li, Alberta Research Council, Edmonton, *CANADA* *"From Animal Waste to Value-added Products"*
	Dr. Debasish Kuila, North Carolina A & T State University, Greensboro, USA. *"Synthesis and Characterization of Silica Encapsulated Mono- and Bi-Metallic Nanocatalysts and their Potential In Steam Reforming Reactions"*
1:00 pm - 2:00pm	Lunch
2:00 pm - 4:00 pm	**Short Presentations Session/ Informal Discussions** 15-20 minute presentations by interested participants
4:00 pm - 6:00 pm	**Poster Session /with Coffee**
6:00 pm - 7:30pm	Sign up for Breakout Sessions/Free Time
7:30 pm - 9:30pm	Dinner
9:30 pm -	**Social Hour**

WEDNESDAY (August 6)

8:00 am - 9:00 am	Breakfast
9:00 am - 10:30 am	**Presentations** **Dr. Kyoung Ro**, USDA-ARS Coastal Plains Soil, Water & Plant Research Center, Florence, *USA* *"Livestock Wastes Processing Options"* **Dr. Isabel Lima,** United States Department of Agriculture, New Orleans, *USA* *"Conversion of Animal Manure to Chars and their Use as Adsorbents for Select Metal Ions"* **Dr. Heather Dettman,** Natural Resources Canada, Alberta, *CANADA* "From Liquid Biomass Waste to Transportation Fuels"

	Dr. Devinder Mahajan, Stony Brook University and Brookhaven National Laboratory, Long Island, *USA* *"Liquid Fuel Production Options from Biomass"*
10:30 am - 11:00 am	Coffee Break
11:00 am – 1:00 pm	**Breakout Sessions (Concurrent)**
	Session I: Bio-based Waste Processing
	Session 2: Crop-based Biomass Processing Discussion Leaders: Kyoung Ro & Heather Dettman
	Session 3: Production and Storage of Fuels and Chemicals Discussion Leaders: Ayusman Sen and Charles (Andy) Miller
1:00 pm - 2:00 pm	Lunch
2:00 am - 5:00 pm	**Breakout Sessions (Concurrent-contd.)**
8:00 pm - 10:00 pm	**Conference Banquet**
1:00 pm -	**Social Hour**

THURSDAY (August 7)	
8:00 am - 9:00am	Breakfast
9:00 am - 11:30 am	**Breakout Sessions: Wrap-up**
10:30 am - 11:30 am	**Breakout session summaries** Presentations by Discussion Leaders
11:30 am -	**Concluding Remarks** D. Mahajan, P. Somasundaran, and K. Ro
1:00 pm - 2:00pm	Lunch
	Adjournment

APPENDIX III

LIST OF CONFERENCE PARTICIPANTS

Engineering Conferences International
Participants List

International Workshop on Defining Issues in Biofuels R&D
Grand Hotel San Michele
Cetraro (Calabria), Italy

List of Participants

Duane Abata
Dean of Engineering
South Dakota School of Mines and Technology
501 East St. Joseph Street
Rapid City, SD 57701-3995
USA
Phone: 1-605-394-5264
Fax: 1-605-394-5266
Email: duane.abata@sdsmt.edu

Ho Nam Chang
Professor
KAIST
Gwahangno 335
Yuseong-gu
Daejeon 305-701
KOREA
Phone: 82-42-869-3912
Fax: 82-42-869-3910
Email: hnchang@kaist.edu

Elizabeth Chavolla
FAO/Universita Roma Tre
Via Delle Terme Di Caracalla
Rome 00153
ITALY
Phone: 39-06-570-53244
Fax: 39-06-570-53250
Email: liza-chavolla@hotmail.com

Richard Coffin
Microbiologist
Naval Research Laboratory
4555 Overlook Ave., SW
Bldg 207 Code 6110
Washington, DC 20375
USA
Phone: 1-202-767-0065
Fax: 1-202-767-0062
Email: rick.coffin@nrl.navy.mil

Cynthia Collins
Rensselaer Polytechnic Institute
110 8th St
Biotech Center, Rm 2125
Troy, NY 12180
USA
Phone: 1-518 276-4178
Fax: 1-518-276-4233
Email: ccollins@rpi.edu

Heather Dettman
Natural Resources Canada
1 Oil Patch Drive, Suite A202
Devon, Alberta T9G 1A8
CANADA
Phone: 1-780-987-8629
Fax: 1-780-987-5349
Email: Heather.Dettman@nrcan-rncan.gc.ca

Carmen María Fernandez Marchante
Universidad De Castilla La-Mancha
Avd/ Camilo José Cela S/n
Ed. ITQUIMA
Ciudad Real 13071
SPAIN
Phone: 34-66-118-7730
Fax: 34-92-629-5242
Email: carmenm.fmarchante@uclm.es

Gerard Goma
INSA LISBP
135 Av Rangueil
Toulouse Midi Pyrenees 31077
FRANCE
Phone: 33-561-55-9405
Fax: 33-561-55-9400
Email: goma@insa-toulouse.fr

Thorsten Hamann
Imperial College London
South Kensington Campus
Sir Alexander Fleming Building (609)
London SW7 2AZ
UNITED KINGDOM
Phone: 44-20-7594-3886
Fax: 44-20-7594-5390
Email: thamann@imperial.ac.uk

Martin Held
Group Leader
ETH Zürich
Universitätstr. 6
Zürich 8092
SWITZERLAND
Phone: 41-44-632-4315
Fax: 41-44-632-1993
Email: held@ipe.mavt.ethz.ch

List of Participants

Barbara Hickernell
Director
Engineering Conferences International
Six MetroTech Center
Brooklyn, NY 11201
USA
Phone: 1-718-260-3743
Fax: 1-718-260-3754
Email: barbara@eci.poly.edu

Patrick Hunt
USDA-ARS
2611 W. Lucas Street
Florence, SC 29501
USA
Phone: 1-843-669-5203 x 101
Fax: 1-843-669-6970
Email: patrick.hunt@ars.usda.gov

Kando Janga
Norwegian University of Science and Technology
Sem Sælandsvei 4
Trondheim 7491
NORWAY
Phone: 47-735-50537
Fax: 47-735-94080
Email: kando.janga@chemeng.ntnu.no

Chishimba Kantu
Shell Global Solutions International BV
Badhuisweg 3
Amsterdam, Nord Holland 1030 BN
THE NETHERLANDS
Phone: 31-20-630-2950
Fax: 31-20-630-3964
Email: Chishimba.Kantu@shell.com

Debasish Kuila
North Carolina A&T State University
1601 E. Market Street
Science Building (348)
Greensboro, NC 27411
USA
Phone: 1-336-285-2243
Fax: 1-336-334-7124
Email: dkuila@ncat.edu

Xiaomei Li
Alberta Research Council
250 Karl Clark Road
Edmonton, Alberta T6N 1E4
CANADA
Phone: 1-780-450-5290
Fax:
Email: Xiaomei.Li@arc.ab.ca

Isabel Lima
U.S. Dept of Agriculture
ARS, Soutern Regional Research Center
1100 Robert E. Lee Blvd
New Orleans, LA 70124
USA
Phone: 1-504-286-4515
Fax: 1-504-286-4367
Email: isabel.lima@ars.usda.gov

Devinder Mahajan
Brookhaven National Laboratory
University of Stony Brook
Building 815
Upton, NY 11973-5000
USA
Phone: 1-631-344-4965
Fax: 1-631-344-7905
Email: dmahajan@bnl.gov

Emiliano Maletta
CIEMAT
Avenida Complutense 22
Madrid 28040
SPAIN
Phone: 34-91-346-6058
Fax: 34-91-346-0939
Email: emiliano.maletta@ciemat.es

Charles Miller
Acting Chief, Atmospheric Protection Branch
(E305-02)
US Environmental Protection Agency
109 TW Alexander Drive
MD: E305-02
Research Triangel Park, NC 27711
USA
Phone: 1-919-541-3497
Fax: 1-919-541-7885
Email: fuller.gloria@epa.gov

William Neill
National Research Council Canada
ICPET, Building M-9
1200 Montreal Road
Ottawa, ON K1A 0R6
CANADA
Phone: 1-613-990-2408
Fax: 1-613-957-7869
Email: stuart.neill@nrc-cnrc.gc.ca

List of Participants

Martin Olazar
Professor
University of the Basque Country
Bº Sarriena S/n
Leioa, Bizkaia 48940
SPAIN
Phone: 34-94-601-2527
Fax: 34-94-601-3500
Email: martin.olazar@ehu.es

Wolfgang Quecke
General Manager
Montan-Grundstucksgesellschaft MbH
Am Technologiepark 28
Essen 45307
GERMANY
Phone: 49-20-177-1705
Fax: 49-20-1177-1704
Email: wolfgang.quecke@mgg.de

John Regalbuto
National Science Foundation
4200 Wilson Blvd.
Arlington, VA 22230
USA
Phone: 1-703-292-8371
Fax: 1-703-292-9147
Email: jregalbu@nsf.gov

Kyoung Ro
USDA-ARS
2611 W. Lucas St
Florence, SC 29501
USA
Phone: 1-843-669-5203 x107
Fax: 1-843-669-6970
Email: kyoung.ro@ars.usda.gov

Naurang Saini
Universita' Di Roma "La Sapienza"
Dipartimento Di Fisica
P.Le Aldo Moro 2
Roma IT 00185
ITALY
Phone: 39-06-4991-4387
Fax: 39-06-495-7697
Email: naurang.saini@roma1.infn.it

Guillermo San Miguel
Universidad Politécnica De Madrid
C/ José Gutiérrez Abascal, 2
Madrid 28006
SPAIN
Phone: 34-91-336-3189
Fax: 34-91-336-3009
Email: g.sanmiguel@upm.es

Byoung-In Sang
Korea Institute of Science and Technology
39-1 Hawolgok-dong, Sungbuk-ku
Seoul 136-791
KOREA
Phone: 82-2-958-6751
Fax: 82-2-958-5839
Email: biosang@me.com

Ayusman Sen
Pennsylvania State University
Department of Chemistry
University Park, PA 16802
USA
Phone: 1-814-863-2460
Fax: 1-814-865-1543
Email: asen@psu.edu

Poonam Singh Nee' Nigam
Director
University of Ulster
Cromore Road
Coleraine, Londonderry BT52 2HP
UNITED KINGDOM
Phone: 44-28-7032-4053
Fax: 44-28-7032-4965
Email: p.singh@ulster.ac.uk

Matthew Smith
USDA ARS
10300 Baltimore AV
B-306 BARC-E
Beltsville, MD 20705
USA
Phone: 1-301-504-9100
Fax: 1-301-504-8162
Email: matt.smith@ars.usda.gov

Donovan Smook
SASOL
1 Klasie Havenga Street
Sasolburg, Free State 1947
SOUTH AFRICA
Phone: 27-16-960-2830
Fax: 27-011-522-4588
Email: donovan.smook@sasol.com

List of Participants

P. Som Somasundaran
Professor
Columbia University
School of Engineering & Apllied Science
500 W 120 St, Room 905 A
New York, NY 10027
USA
Phone: 1-212-854-2926
Fax: 1-212-854-8362
Email: ps24@columbia.edu

Kenji Yamagishi
Mitsubishi Chemical Group Science and Technology
Reserch Center, Inc.
1000 Kamoshida-cho,Aoba-ku,
Yokohama, Kanagawa 227-8502
JAPAN
Phone: 81-45-953-4217
Fax: 81-45-963-4462
Email: 2704833@cc.m-kagaku.co.jp

Wlodzimierz Zmierczak
Research Professor
University of Utah
135 South 1460 East
Room 412
Salt Lake City, UT 84112-0114
USA
Phone: 1-801-581-3060
Fax: 1-801-581-4937
Email: w.zmierczak@utah.edu

APPENDIX IV

SUMMARY OF SAMPLE BIOFUELS-RELATED INITIATIVES
IN
SELECTED COUNTRIES

CANADA
SPAIN
SOUTH KOREA
USA

Biofuels Initiatives in Canada

Heather D. Dettman
Natural Resources Canada, CanmetENERGY
1 Oil Patch Drive, Devon, Alberta T9G 1A8

Email: Heather.Dettman@nrcan-rncan.gc.ca

ABSTRACT

In Canada, energy from renewable and hydro-sources comprise 17% of Canada's current energy supply. To encourage increased use of biofuels, the federal government has created initiatives for both promoting research and development of new technologies, and providing incentives for commercialization of technologies. Emphasis is being placed on developing and implementing technologies to make use of renewable resources across the country that address regional needs. Some examples include helping the forest industry by promoting use of forest biomass including trees infected with Mountain Pine Beetle, and re-vitalization of rural economies and Aboriginal communities to help Canadian industry and communities meet the challenges of improving efficiency and reducing toxic air emissions through development of local bio-resources. Activities will develop new and improved technologies for producing energy from plants, wastes and microorganisms as well as develop the knowledge for moving towards a bio-based economy, and support the development of associated regulations. Summaries of both federal and provincial government programs are given.

INTRODUCTION

Currently in Canada, energy from renewable and hydro-sources comprise 17% of Canada's energy supply (see Figure 1).

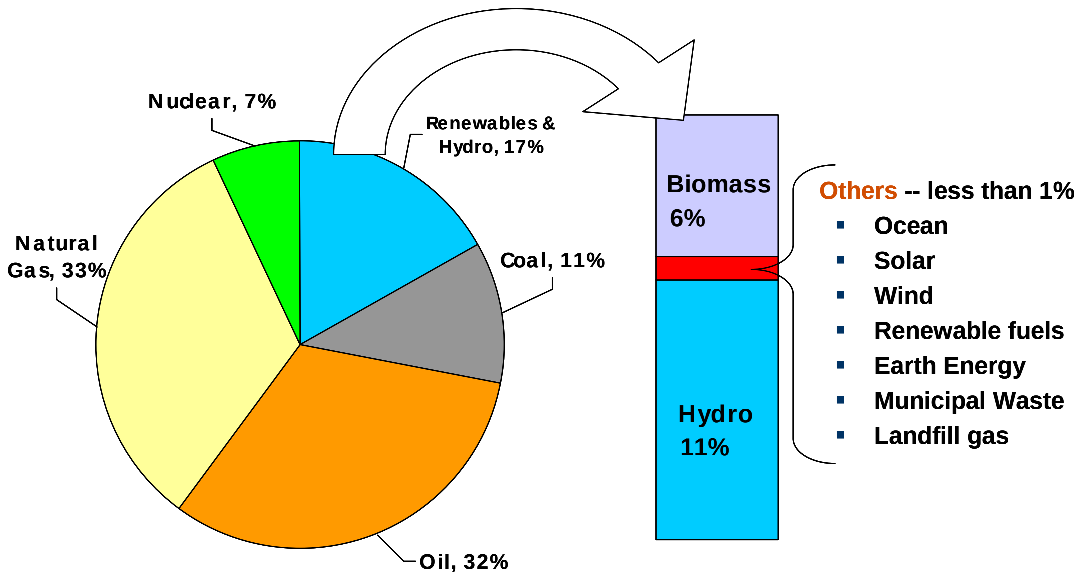

Figure 1 Bioenergy content in Canada's energy supply (used with permission from OERD at NRCan)

To encourage increased use of biofuels, the federal government has created initiatives for both promoting research and development of new technologies, and providing incentives for commercialization of technologies. Emphasis is being placed on developing and implementing technologies to make use of renewable resources across the country that address regional needs. Some examples include helping the forest industry by promoting use of forest biomass including trees infected with Mountain Pine Beetle, and re-vitalization of rural economies and Aboriginal communities to help Canadian industry and communities meet the challenges of improving efficiency and reducing toxic air emissions through development of local bio-resources. Activities will develop new and improved technologies for producing energy from plants, wastes and microorganisms as well as develop the knowledge for moving towards a bio-based economy, and support the development of associated regulations.

RESEARCH, DEVELOPMENT & DEMONSTRATION

The research, development, and demonstration (RD&D) of new technologies for conversion of biomass feedstocks into biofuels in Canada is coordinated by the Canadian Biomass Innovation Network (CBIN) http://www.cbin-rcib.gc.ca/ . CBIN is interdepartmental and promotes research in the areas of bioenergy, biofuels, industrial bioproducts, and bioprocesses that look at existing and new biomass supplies, biomass conversion and utilization technologies, integrated bio-applications, and cross-cutting activities such as strategies, policies, regulations, assessments, and information dissemination. For example, in regards to RD&D for transportation fuels, CBIN is sponsoring research for ethanol production from lignocellulosic materials derived from forestry waste and/or agricultural biomass, and the production of biodiesel from various plant oils and algae. CBIN is primarily funded by Natural Resources Canada's Office for Energy Research and Development (NRCan-OERD) http://www.nrcan.gc.ca/eneene/science/index-eng.php , the Government of Canada's coordinator of energy RD&D activities. For detailed descriptions of the projects funded, please see the CBIN website http://www.cbin-rcib.gc.ca/ .

INCENTIVES FOR BIOFUELS PRODUCTION AND ENERGY EFFICIENCY

Transportation Fuels, including Ethanol

There is a 9-year program that supports the production of renewable alternatives to gasoline and diesel and encourages the development of a competitive Canadian industry for renewable fuels. It will make investments in production facilities more attractive by partially offsetting the risk associated with fluctuating feedstock and fuel prices. For example, incentive rates will be up to $0.10/L for renewable alternatives to gasoline and up to $0.20/L for renewable alternatives to diesel for the first 3 years, which will decline thereafter. Incentives are available to eligible facilities with a nameplate capacity of at least 3 M litres for production of renewable alternatives to diesel or 5 M litres for production of renewable alternatives to gasoline constructed before March 31, 2011, subject to program volume limits, with a cap of 30% of program volume limits per company, for up to 7 years.

As well, the Canadian government has funds for repayable contributions of up to $25 M per project or 25% of eligible project costs (which ever is less) for the construction or expansion of transportation biofuel production facilities. Funding is provided for projects that use agricultural feedstocks to produce biofuels and that have new agricultural producer equity investments in the projects equal to, at minimum, 5% of the total eligible project costs. This initiative provides an opportunity for agricultural producers to diversify their economic base and participate in the biofuels industry through equity investment/ownership in biofuels production facilities helping them overcome the challenges of raising the capital necessary for the construction or expansion of biofuel production facilities.

With regards to ethanol, there are plans to accomplish a four-fold (750 M litres) increase in Canada's annual ethanol production and use. This could mean that 25% of Canada's total gasoline supply would contain 10% ethanol. Contingent loan guarantees are provided to encourage financing for new plants that produce ethanol from biomass if all or part of the excise gasoline tax on ethanol is imposed before December 31, 2010. This initiative promotes increased supply and use of ethanol produced from biomass; provides for funding of activities such as public education on fuel ethanol, analysis of fuel ethanol markets, and producer economics; and provides a liaison with provinces/territories and industries that are interested in ethanol plant expansion. This initiative is part of the Government of Canada’s Action Plan 2000 on Climate Change and renews the National Biomass Ethanol Program (NBEP) launched in the mid-1990s to help overcome lender resistance to investing in ethanol plants as a result of uncertainty about the excise tax policy.

Renewable Feedstocks for Electricity

This program aims to increase Canada's supply of clean electricity from renewable sources including biomass by providing $0.01/kWh for up to 10 years to eligible low-impact, renewable electricity projects. Overall, the program will encourage the production of 14.3 terrawatt hours of new electricity from renewable energy sources that is enough electricity to power about one million homes.

Efficiency Improvement

Business and industry are being encouraged to reduce energy waste and to use renewable energy sources by providing an accelerated capital cost allowance at a rate of 30% for energy production equipment. Eligible investments include co-generation and specified waste-fueled electrical generation systems, heat recovery systems, and specified waste-fueled heat production equipment.

HIGHLIGHTS OF BIOFUEL INITIATIVES BY PROVINCIAL GOVERNMENTS

British Columbia

British Columbia (BC) is focusing on biofuel options for producing both electricity and transportation fuels. BC Bioenergy Network (BCBN) is an industry-led association that acts as a catalyst for deploying near-term bioenergy technologies and to promote research for the development and demonstration of new bioenergy technologies that are most appropriate for BC. For electricity, BC Hydro will be looking for clean options for utilization of wood-fibre fuel sources, including wood infected by the mountain pine beetle. To encourage biofuel utilization, BC government has implemented carbon taxation of virtually all fossil fuels including gasoline, diesel, natural gas, coal, propane, and home heating fuel on an increasing scale. For example, the carbon tax of $0.0241/L for gasoline will rise gradually to $0.0827/L over four years. This initiative encourages the use of biofuels and renewable energy as these will either not be subject to the carbon tax or the tax will be refundable.

Alberta

The Alberta government is investing in the development of technologies related to biofuels to assist their agricultural community. Programs focus on research and development in feedstock improvement, production of transportation fuels, and waste utilization. Feedstock development has produced "Triticale" as a bio-industrial cereal crop. The Canadian Triticale Biorefining Initiative (CTBI) has 6 strategic priorities including: competitiveness of triticale biorefining; biorefining modern triticale varieties (primary manufacturing); platform chemicals (secondary manufacturing); polymers and advanced materials (tertiary manufacturing); future competitiveness as triticale crop production; and enabling biotechnology. For transportation fuel, research is focused on improving the production of ethanol from cereal grains. This program is composed of 3 technology platforms namely, fermentation, chemical, and thermal. Anticipated outcomes from this research include the quantification and determination of ethanol yields of all major Canadian prairie crops; chemical profiling of crops and fermentation byproduct streams; fermentation to value-added products (for example, xylitol); and identification of technical or process issues and barriers with respect to the above crops in the ethanol manufacturing process. Bio-waste utilization development for biofuel production builds on the anaerobic digestion "Integrated Manure Utilization System" (IMUS) technology platform developed by the Alberta Research Council (ARC) and its partners. This program will adapt the IMUS technology to utilize variable feedstocks (i.e. food processing wastes, specified risk materials, rendering materials, thin stillage, manure, and their admixtures) to produce biogas and novel products to diversify Alberta's agricultural industry.

The Alberta government has also developed an incentive program to encourage the production and incorporation of bioenergy products (ethanol, biodiesel, biogas-electrical) within the marketplace. Credits are given to producers of biofuels or biogas of $0.14/litre (production capacity less than 150 M litres/year, up to a maximum of $15 M/year) or $0.09/litre (production capacity of or greater than 150 M litres/year, up to a maximum of $20 M/year and total of $75 M for the project). Those generating electricity receive $0.02/kWh (production capacity of or greater than 3 MW) or $0.06/kWh (production capacity less than 3 MW).

Saskatchewan

The focus of the Saskatchewan government is on the implementation of bio-based transportation fuel projects that include the rural community. In particular, they have passed legislation for an average of 7.5% ethanol in gasoline in the province and correspondingly are providing incentives for ethanol production that is produced and consumed in Saskatchewan. For example, the government will provide repayable contributions of up to $10 M per project for the construction or expansion of transportation-biofuel production facilities in Saskatchewan that have a minimum of 5% farmer-community investment. This program provides an opportunity for farmers and communities to participate in the value-added biofuels industry in Saskatchewan through investment ownership in biofuels facilities.

Manitoba

Manitoba government has passed legislation for at least 8.5% ethanol in gasoline in the province. They have implemented a decreasing incentive scale for ethanol production that is produced and consumed in Manitoba. In particular, ethanol producers will currently receive a grant of $0.20/litre that will decrease to $0.10/litre in 2013. For biodiesel, there is a Provincial Fuel Tax Credit of $0.115/L, provided the biodiesel is consumed in Manitoba.

Ontario

The Ontario government has created programs to encourage development of gas, transportation fuel, and electricity production from renewable resources. For biogas, their program is designed to promote sustainable biogas production in the Ontario agri-food and rural sectors. The biogas systems would be targeted to achieve reductions in GHG emissions, increase production of renewable energy, promote use of digestate as a land-applied nutrient, improve biogas utilization, and foster agricultural innovation and economic opportunities. Phase 1 will support

70% of the costs of feasibility, design and planning studies, to a maximum of $35,000 per project. Phase 2 will provide 40% of construction, implementation and commissioning costs for biogas systems, to a maximum of $400,000 (total of Phase 1 & 2 per project).

For transportation fuels in Ontario, ethanol and biodiesel production is being encouraged. The government has set a requirement of an annual average of 5% ethanol in gasoline. To support this need, they will provide 1) capital assistance (not exceeding $0.10/L of plant capacity) in the form of capital grants or loan guarantees for eligible new or expanding ethanol plants being built in Ontario; 2) operating grants (not exceeding $0.11/L of ethanol produced in a particular year for a maximum of 750 M litres per year paid over a period of up to 10 years) to eligible producers in production from 2007-2017 to address changing market prices; 3) support for independent blenders of ethanol and gasoline; and 4) a R&D fund to pursue opportunities for research and innovation. For biodiesel fuel, there is an excise tax exemption of $0.143/L production as long as the biodiesel is consumed in Ontario.

Production of electricity from renewable feeds is being promoted in Ontario by the setting of a fixed price (feed-in-tariff) for small renewable energy generation projects to make it easier and more cost effective for businesses and entrepreneurs to sell renewable power to the provincial grid. All small-scale renewable energy producers will be able to sell renewable power to the grid for 20 years. Over the next 10 years, this will add up to 1,000 megawatts of renewable power to Ontario's electricity system.

Quebec

The Quebec government is encouraging ethanol and biodiesel production. For ethanol, a goal of 5% ethanol in gasoline will be set by 2012 where the need is expected to be met by next-generation cellulosic ethanol. In the meantime, there is a “Variable Rate Income Tax Credit” to a maximum of $0.185/L of ethanol production, provided the ethanol is produced and consumed in Quebec. Each year, there is a maximum of $182.4 M in financial assistance available to each eligible corporation, for a maximum of 10 years. For biodiesel, the government will give a tax refund of $0.162/L on the purchase of pure (B100) biodiesel fuel (> 3000 L) that is not blended with any other type of fuel, provided the biodiesel is consumed in Quebec.

New Brunswick

The New Brunswick government is focused on renewable biofuels for electricity production. By 2016, the government requires that NB Power purchase 10% of it electricity sales from new renewable sources.

Nova Scotia

The government of Nova Scotia is promoting the production of biodiesel in their province through a “motive fuel” tax exemption of $0.154/L for biodiesel produced in Nova Scotia (biodiesel portion of blends only) that meets the American Society for Testing and Materials fuel-quality specification.

Other Programs and Information

Other biofuels programs continue to be developed in Canada. See the CBIN website for current information http://www.cbin-rcib.gc.ca/ .

ACKNOWLEDGEMENTS

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Summary of biomass and biofuel efforts in Spain

Guillermo San Miguel[1*], Jorge Servert[1], Laureano Canoira[2]

[1] ETSI Industriales, Department of Energy Engineering, Universidad Politécnica de Madrid, C/ José Gutiérrez Abascal, 2, 28006 - Madrid.
[2] ETSI Minas, Department of Chemical Engineering and Fuels, Universidad Politécnica de Madrid, C/ Ríos Rosas, 21, 28003 - Madrid.

***Corresponding author:** g.sanmiguel@upm.es

ABSTRACT

Following environmental and economic motivations, most countries in the world are confronting the challenge of reducing both their dependence on fossil fuels and the emission of greenhouse gases. In line with the international commitments assumed as a member of the European Union (EU) and also as a signatory of the Kyoto Protocol, Spain developed a program (*Plan de Energías Renovables 2005-2010*) that forms the basis of the national strategy for the promotion of renewable energies. The general objectives set in this plan include covering with renewable sources: 12.1 % of primary energy, 30.3 % of electricity and 5.83 % of the transportation fuels consumed.

Despite significant progress, Spain is still far from meeting these objectives primarily due to slow growth in the demand for biofuels and the limited success of biomass fired power plants. The evolution in other technologies has been faster, situating Spain as world a leader in photovoltaic and wind energy. In the midst of intense regulatory, commercial and R&D activity, this paper analyses the current situation with respect to the production of renewable energies, focusing primarily on the use of biomass resources. The paper offers a general view of policy and regulatory background, illustrates current progress towards meeting national objectives and provides a brief description of key projects and activities in the area of biofuel production and biomass valorization.

1. CURRENT ENERGY SITUATION IN SPAIN.

1.1 Primary energy.

Since its accession to the European Union in 1986, Spain has undergone a rapid economic expansion that has been accompanied by a similarly fast growth in energy consumption. For instance, between 1990 and 2005, Spanish Gross Domestic Product (GDP) grew by 49.1 % compared to 12 % in the European Union. In that same period, consumption of primary energy and emission of greenhouse gases (GHG) in Spain increased by 61.3% and 61.6 %, respectively (MMA, 2007).

Despite the scarcity of fossil fuels in its territory, the Spanish energy system is highly dependent on this type of energy. Imports in 2007 accounted for 64.0 % of the coal, 99.5 % of the oil and 99.1 % of the natural gas consumed. As a result, only 20.8 % of the 146.6 Million tons of oil equivalent (Mtoe) of primary energy consumed were met by national resources (MITYC, 2008). This situation is illustrated in Figure 1, which shows that 48.1 % of the primary energy consumed in Spain comes from petroleum derivates, 21.5 % from natural gas, 13.7 % from coal, 9.8 % from nuclear power and only 6.9 % from renewable resources. Biomass, primarily used for heat applications in small combustion plants, was by far the most widely used renewable energy source (2.7 %) followed by wind and hydraulic energy (1.6 % each) used for the generation of electricity.

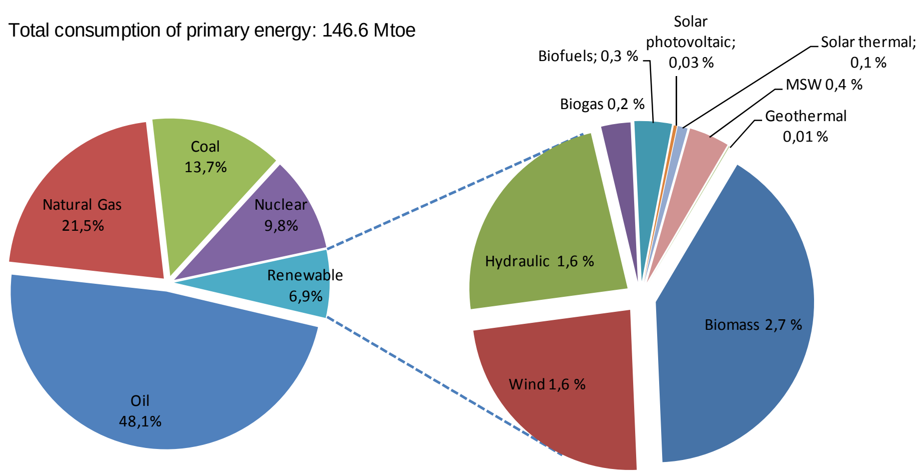

Figure 1: Breakdown of primary energy sources in Spain (extracted from MITYC, 2008).

1.2 Electricity generation.

In 2007, consumption of electricity in Spain amounted to 312.138 GWh. As shown in Figure 2, this electricity was generated from the following sources: 31.6 % natural gas, 24.1 % coal-fired power plants, 17.6 % nuclear power stations, 6.2 % oil derived fuels and 20.0 % from renewable resources.

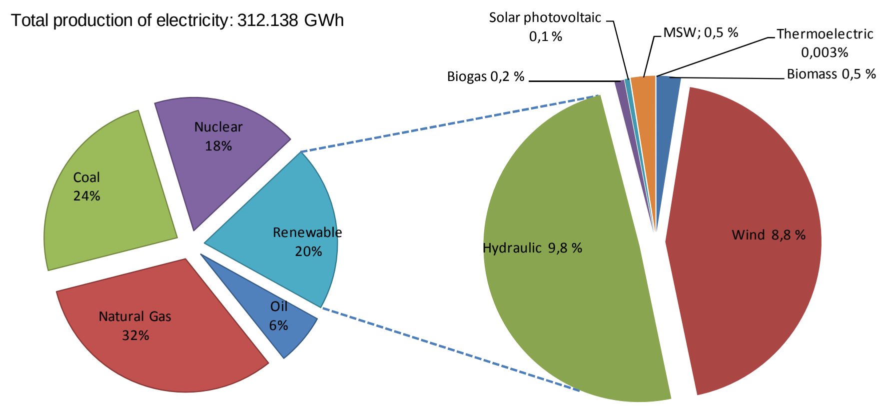

Figure 2: Breakdown of electricity sources in Spain (extracted from MITYC, 2008).

In the last decade, the production of electricity from renewable sources has almost doubled, from 36.609 GWh in 1997 to 62.361 GWh in 2007. As shown in Figure 2, the highest input currently comes from hydraulic and wind energy, which account for 9.8 % and 8.8 % of the production, respectively. The contribution from other renewable energy sources (photovoltaic, biogas, biomass, municipal solid waste) was marginal, accounting for the remaining 1.4 %.

2. RENEWABLE ENERGIES IN SPAIN.

2.1 Current situation.

Prior to the application of any incentives, the production of renewable energies in Spain relied essentially on small scale combustion of biomass for heat production and also on the generation of electricity in hydraulic plants. In the late nineties, Spain started to develop a public system for the promotion of renewable energies that has been very effective in the deployment of wind and more recently photovoltaic energy.

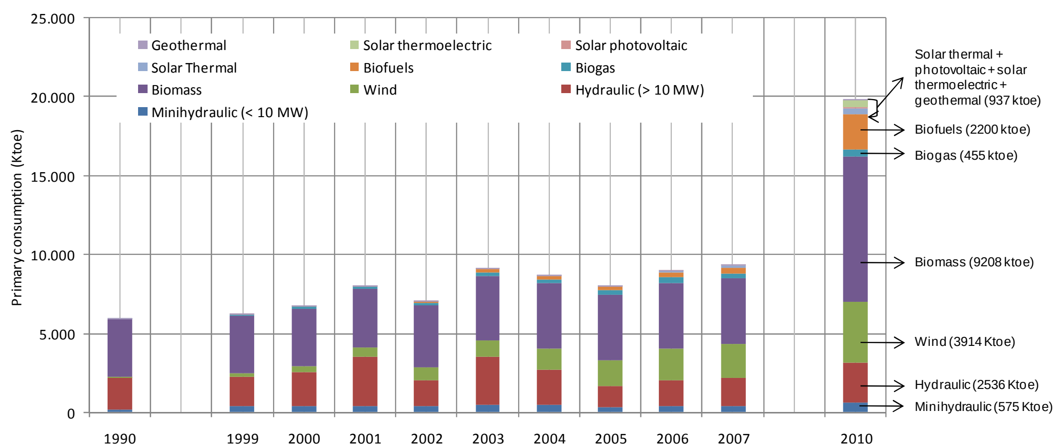

Figure 3: Evolution in the production of renewable energies in Spain (Extracted from MITYC, 2008 and MITYC, 2004).

As illustrated in Figure 3, the consumption of renewable energy increased by 56 % between 1999 and 2007, primarily as a result of a rapid expansion in wind (from 232 to 2200 ktoe) power. A rapid growth in photovoltaic generation (from 1 to 75 ktoe) has also taken place over this period, although its overall contribution still remains very limited. In contrast, the production of energy from biomass and hydraulic plants has remained stable. This overall growth, however, is insufficient considering the ambitious objectives set in the national strategy renewable energies (Plan de Energías Renovables 2005-2010).

2.2 Policy and legislation.

Spanish policy on renewable energies needs to be studied within a wider international context. The European Union (EU) sets a common ground, drafting a general strategy and producing basic legislation that is then transposed and developed by each Member State. International agreements, like the Kyoto Protocol, include further commitments that affect the development of national regulations.

This section provides a summary of national and international policy and legislation that is currently affecting the use of renewable energies in Spain, particularly focusing on that related to biofuels and biomass.

2.2.1 International Context.

The Kyoto Protocol, which was ratified by the EU in 2002 and came into force in 2005, allowed Spain to increase its greenhouse gas emissions by 15% between 1990 and the reference period 2008-2012. In 2007, Spain emitted 441.4 million tons of CO_2 equivalent, representing a 52.3 % increase from the baseline value.

The recently approved *Real Decreto 1030/2007*, which amends the National Plan for the Assignment of Green House Gases Emission Allowances, increases the emission allowance from 15 % to 37%. This figure is obtained from the addition of the 15% original allowance, plus 2% absorption of CO_2 by carbon sinks plus a further 20 % from the acquisition of carbon credits under the Kyoto Protocol Flexibility Mechanisms.

2.2.2 European Context.

The *Renewable Energy White Paper* (EU, 1997) is the origin of most of the current EU policy on renewable energies. This document defined the first action plan aimed at promoting a wider application of renewable energies and set the target of doubling its use from 6% in 1996 to 12% in 2010.

The Renewable Energy Sources Directive (*Directive 2001/77/EC on the promotion of the electricity produced from renewable energy source in the internal electricity market*) defined a new framework that favored the production of electricity from renewable energy sources. The directive sets specific targets for Member State and includes technical and administrative measures intended to increase the contribution of renewable sources in the EU to 21% by 2010. The Biofuels Directive (*Directive 2003/30/CE on the promotion of the use of biofuels or other renewable fuels for transport*) was aimed at promoting the use of renewable liquid fuels for transport. The directive requires Member States to take measures to ensure that 5.75 % of conventional transport fuels (petrol and diesel) are replaced with biofuels by 2010. An intermediate target of 2.0 % is also set by the end of 2005. The commitments in this Directive are not legally binding and most countries, including Spain, did not meet the 2005 target. *Directive 2003/96/EC restructuring the Community framework for the taxation of energy products and electricity*, defines a common ground for the taxation of energy products and electricity within the EU. The Directive sets minimum rates of taxation for conventional fossil fuels and allows Member States to exempt or reduce taxes on biofuels.

Directive 2003/17/EC relating to the quality of petrol and diesel fuels, states technical specifications for transportation fuels. The Directive modifies the definition of diesel (EN 590) and petrol (EN 228) to allow the incorporation of up to 5 % of biodiesel or bioethanol. This directive is being revised to allow the incorporation of higher proportions of renewable fuels. The *Biomass Action Plan* (EU, 2005) sets out a strategy aimed at increasing the use of biomass from forestry, agriculture and waste materials for energy purposes. The objective is to increase its demand from the 69 Mtoe estimated in 2004 to around 150 Mtoe by 2010. The Plan announces more than 20 actions including the promotion of biofuels obligations, support for developing countries that want to produce transport biofuels and revision of fuel standards.

The *Energy Green Paper: A European Strategy for Sustainable, Competitive and Secure Energy* (EU, 2006) describes the future energy policy in Europe. The paper is built on three objectives: sustainability; competitiveness; and security of supply. Key suggestions include promoting energy efficiency and the use of renewable energies.

Climate Action (EU, 2008): in a recent Communication, the European Commission produced a package of proposals that will deliver the European commitments to fight climate change and promote renewable energy. The objectives for 2020 include:

- Reduce energy consumption by 20%
- Reduce greenhouse gases by 20%
- Increase the share of renewable energy to 20%

In line with this document, the EU is also working on a proposal for a new *Directive on the promotion of the use of energy from renewable sources* (EU, 2008).

2.2.3 National context.

Plan de Energias Renovables 2005-2010 (Renewable Energy Plan) (MITYC, 2005), which was approved in 2005, is the key document to understand the Spanish strategy for the promotion of renewable energies. In the context of international regulations, this Plan sets a series of objectives for 2010 including:

- 12.1 % of primary energy from renewable sources.
- 30.3 % of electricity production from renewable sources.
- 5.83 % of transport fuels from renewable sources.

Plan de Energías Renovables envisaged the production of 20,200 ktoe of energy from renewable sources for the year 2010, of which 3,914 ktoe would come from wind power, 5,138 ktoe from biomass power plants, 4,070 ktoe from biomass to heat plants and 2,200 ktoe from transport biofuels. Table 1 shows a more detailed description of the objectives and Figure 3 illustrates the evolution in the production of energy from different renewable sources over the last decade.
Table 1: Energy production from renewable sources in Spain (extracted from MITYC, 2008) and objectives for 2010 (Extracted from MITYC, 2005).

Wind power installed capacity has increased very rapidly in Spain over the last few years. Only in 2007, this value increased by 3,515 MW to reach 15,090 MW. The 678 wind parks currently in operation generated 2,368 ktoe of Energy, which put Spain in second position worldwide behind Germany, and ahead of the United States. However, a 65 % increase is still required over the next three years to meet the 2010 target.

Biomass energy has not developed as fast as expected, primarily due to insufficient interest in the construction of biomass power plants for electricity generation and also as a result of the late implementation of biofuels regulations. The 396 MW installed capacity registered in 2007 for biomass power plants is far from the expected 2,039 MW planned for 2010. To close this gap, new mechanisms are being introduced to promote joint combustion of biomass in conventional fossil fuel fired power stations.

With respect to biofuels, *Plan de Energías Renovables* set the objective of replacing 5.83 % (by volume) of transport fuels by 2010. The Plan describes the production of 1,412 ktoe of biodiesel (86 % from pure vegetable oils and 14 % from used oils) and 750 ktoe of bioethanol (73 % from cereals and biomass, and 27 % from wine derivates). Spain is currently very far from these objectives and did not meet the 2% target set for 2005 in the Biofuels Directive.
Owing to strong economic incentives, Spain has increased very rapidly the production of photovoltaic energy. The installed capacity registered in 2007 (638 MW) exceeded by more than 50 % the objective stated in *Plan de Energías Renovables*. However, this type of energy contributes very little to the overall renewable energy share (0.25 % of the 20,200 ktoe). In contrast, the development of solar-thermal and solar thermoelectric energy remains very limited, despite the recent construction of a 11 MW Concentrating Solar Power (CSP) plant in Sanlucar la Mayor (Sevilla). However, this technology is going to see a very rapid expansion as there are around 2,000 MW of CSP currently under development.

In summary, an analysis of the results published for the year 2007 (MITYC, 2008) shows a yearly increase of 800 ktoe in the production of renewable energies for a total generation of 10,300 ktoe. Hence, a much faster growth will be required to reach the 20,200 ktoe objective set for 2010. Low compliance is primarily observed in the areas of biomass to electricity, biomass to heat, transport biofuels and solar thermal (less than 12 % of the objectives reached). Better agreement is found in the generation of wind (56.6 %) and photovoltaic (132 %) energy.

	2007		Renewable Energy Plan - 2010	
	Installed capacity (MW)	Production in terms of primary energy (ktoe)	Installed capacity (MW)	Production in terms of primary energy (ktoe)
ELECTRICITY GENERATION				
Hydraulic (> 50 MW)	13.521	1.623	13.521	1.979
Hydraulic (10-50 MW)	2.999	365	3.257	557
Hydraulic (< 10 MW)	1.852	353	2.199	575
Biomass	396	585	2.039	5.138
M.S.W.	189	649	189	395
Wind	15.090	2.368	20.155	3.914
Solar photovoltaic	638	40	400	52
Biogas	166	202	235	455
Solar thermal	11	2	500	509
Total electricity	34.862	6.187	42.495	13.574
THERMAL APPLICATIONS				
Biomass		3.452		4.070
Solar thermal low temperature	1,198,453 m2	93	4,900,000 m2	376
Geothermal		8		8
Total thermal energy		3.553		4.454
TRANSPORTATION BIOFUELS				
Total transportation biofuels		382		2.200
TOTAL RENEWABLE ENERGIES		10.122		20.200
CONSUMPTION PRIMARY ENERGY (Ktoe)		146.646		167.100
Reneable energies /Primary energy (%)		6,9		12,1

3. INCENTIVES.

In order to reach the objectives set in the *Plan de Energías Renovables*, the Spanish government has developed a number of financial and fiscal incentives to promote the generation of heat and electricity from renewable sources and also the demand for transport biofuels.

3.1 Electricity.

Ley 54/1997 del Sector Eléctrico (Electric Power Act) establishes the liberalization of the electricity market and creates a "special regime" for electricity generated from renewable resources. For electricity generated under this special regime, the legislation establishes:

- Guaranteed grid access and obligation of the distributor to buy this electricity from the producers.
- A price support mechanism based on the so called "feed in tariff" system.

This "feed in tariff" system allows the producers of electricity to select between one of two ways of obtaining this monetary incentive:

- "Fixed price": the price of each KWh sold to the distribution grid is fixed by law.
- "Fixed premium": the electricity generated is sold in the standard market and the producer gets a fixed bonus on top of the market price.

These incentives and revised annually and take into consideration several factors including: environmental considerations of each energy generation technology; investment and generation costs; energy efficiency; degree of compliance with the objectives set in the *Plan de Energías Renovables*. The costs of implementing this scheme are transferred to the consumers through higher tariffs.

Ley 54/1997 was originally developed by Real Decreto 2818/1998, which was subsequently reformed by Real Decreto 436/2004 and the more recent Real Decreto 661/2007. To have an idea of the current situation, Table 2 summarizes the range of incentives described in the latest *Real Decreto 661/2007*.

For instance, owing to the high cost of solar panels and the limited penetration of this technology, photovoltaic energy was originally allocated a very high "fixed price" (44c€/kWh). This value has been recently revised down to 32 c€/kWh as a result of excessive growth in the sector caused by a sudden reduction in price of solar panels. Much lower incentives have been set for wind (between 6.1 - 7.3 kWh) owing to the lower costs associated and the rapid development of this technology.

Electricity production from biomass is subsidized differently depending on the origin of the biomass. The highest financial support goes to electricity from energy crops (up to 16.0 c€/kWh) and the lowest to industrial biomass (up to 12.6 c€/kWh).

Table 2. Feed in tariffs for electricity generated from different energy sources (extracted from *Real Decreto 661/2007*).

Energy source	**Period**	**Fixed price (c€/kWh)**
Wind energy	First 20 years	7.3
	After 20 years	6.1
Photovoltaic energy	First 25 years	23.0 - 44.0
	After 25 years	18.4 - 35.2
Solar thermal	First 25 years	26.9
	After 25 years	21.6
Geothermal, tidal, waves	First 20 years	6.9
	After 20 years	6.5
Energy crops	First 15 years	14.7 - 16.0
	After 15 years	11.9 - 12.3
Agriculture and forest biomass	First 15 years	10.8 - 15.9
	After 15 years	8.1 - 12.3
Biogas	First 15 years	5.4 - 13.1
	After 15 years	5.4 - 6.5
Industrial biomass	First 15 years	6.5 - 12.6
	After 15 years	6.5 - 8.5

3.2 Transport biofuels.

Ley 53/2002 de Medidas Fiscales, Administrativas y del Orden Social (of fiscal, administrative and social order measures) established a tax exemption for biofuels starting from 2003. The legislation states that this measure is aimed at facilitating the penetration of renewable energies into the market and warns of the possibility of modifying this decision depending on the production costs of fossil fuels and biofuels.

Ley 36/2003 de medidas de reforma económica (economic reform measures) lays down a 10 % special deduction for investments in equipment and installations intended for the conversion of agricultural products into biofuels.

3.3 Heat from renewable energies.

Real Decreto 314/2006 por el que se aprueba el código técnico de la edificación (Technical Buildings Code) requires that between 30% and 70% of the sanitary hot water in new buildings and renovations is produced from solar thermal energy. The exact values depend on the characteristics and the geographical location of the building. This piece of legislation also stipulates subsidies (up to 45 %) and special loans for investments carried out by individuals, private companies and local authorities related for the production of heat from biomass.

4 BIOMASS AND BIOFUEL EFFORTS IN SPAIN: CASE STUDIES.

The coming into effect of regulations has prompted the development of a very active industry in the renewable energy sector. Progress towards meeting the targets stated in *Plan de Energías Renovables* has been significant in some areas like photovoltaic and wind power. Production of biomass derived energy is still behind expectations, and a notable impulse is expected during the next few years. This section provides general information about some key projects undertaken in Spain in the field of energy production from biomass sources.

4.1 Biomass incineration for electricity.

4.1.1 Cereal straw power plant in Sangüesa (Navarra).

Acciona Energía owns and operates a 25 MW power plant in Sangüesa (Navarra). This venture was opened in 2005, consumes 160,000 t of cereal straw and generates 200,000 MWh per year. The plant involved a total investment of 50 million €, employs 26 people full time and has created more than 100 indirect jobs.

The combustion technology is based on a water cooled grate furnace that generates superheated steam (500ºC and 90 bar) that is directed into a steam turbine. According to Acciona Energía, a key technical challenge in this plant related to reducing damage to the boiler by corrosion derived from the high concentration of chlorine and potassium in the cereal straw. The running of this plant also involves a logistic challenge in order to guarantee a continuous supply of straw throughout the year. The process generates an ash residue that is commercialized as a fertilizer (Lopez-Gonzalez et al., 2007).

4.1.2 Electricity from olive oil production residues in El Tejar (Cordoba).

Spain is one of the top producers of olive oil in the world with 900,000 ha dedicated to this activity and a total production that is expected to reach over 1.2 million tons in the 2007/2008 season. *Cooperativa Oleícola El Tejar*, based in El Tejar (Córdoba), is one of the largest cooperative companies in this sector, integrating over 259 smaller companies and associations dedicated to the production of olive oil.

This company is currently the largest producer of biomass derived electricity in Spain, with four power plants operating in El Tejar and Palenciana (Cordoba). These four plants have a combined capacity of 48.3 MW and generate 340,000 MWh per year of electricity from the incineration of olive oil production waste (*alperujo*). A fifth plant (5 MW capacity) is being built in Algodonales (Cadiz) that will generate a further 40,000 MWh. The investment for this plant was 6.1 million €, of which 2.24 million € were subsidized by the Spanish Government.

4.1.3 Hybrid biomass/solar plants.

This novel technology relies on the integration of a solar collector into the water/steam cycle of a biomass power plant. The combination of these two technologies benefits from increased overall energy efficiency, reduced investment for a given power (compared to CSP with molten salts heat storage), and longer operating hours (24 hours a day without the need for heat storage).
In hybrid plants, the solar field and the biomass boiler are connected in parallel. In order to maintain appropriate steam conditions (usually around 450ºC and 70 bar), the flow of water that is fed through the solar field is adjusted depending on the solar irradiation. The biomass boiler operates at different capacities, depending on the solar contribution, to produce a constant electricity output.

From an economic point of view, this approach benefits from the higher feeding tariff established in *Real Decreto 661/2007* for the production of electricity from thermo-solar power, which is paid at 0.28 €/KWh compared to 0.11-0.15 €/KWh for biomass. Several national companies and research centers, including *Investigación, Desarrollo e Innovación Energética* (IDIE), *Universidad Politécnica de Madrid* (UPM) and *Universidad Pontificia Comillas* (UPC), are currently working on the development of hybrid biomass/solar plants with capacities ranging from 3-15 MW, with the first one being expected to run into operation in 2011.

4.2 Biomass incineration for heat generation.

4.2.1 Heat and sanitary water from biomass in Cuellar (Segovia).

This project involved the construction of a centralized system designed to supply heating and hot sanitary water to a neighborhood of approximately 1,000 inhabitants including a school, a cultural centre and a municipal sports centre in Cuellar (Segovia). This project was selected by the EU Directorate-General for Energy and Transport in its Penelope Project Good Practice Database (EU, 2004).

The process consists of three main elements: a 5.95 MW thermal plant fed with biomass (2300 t/year); a system of distribution pipelines (total length 2,500 m) transporting the hot water (200 m^3/h) from the thermal plant to consumption areas; and feeding systems that allow end users to connect to the distribution network. Most of the biomass comes from local wood processing industries (furniture, boards and wood mills). The project involved a total investment of 1.2 million € that was financed by the national and the regional Energy Agencies (IDEA and EREN).

4.3 Transport biofuels.

Spain is currently in the middle of a biofuel turmoil caused by the coming into effect of regulations aimed at meeting the commitments established in the *Plan de Energías Renovables 2005-2010*. Several companies have made large investments to increase their bioethanol and biodiesel production capacity. However, national demand has remained low, due primarily to the late application of regulations. As a result, only 3 of the 30 plants dedicated to the production of biofuels in Spain were operating at full capacity at the beginning of 2008.
This regulation has finally come in the form of Ley 12/2007 (amending the Hydrocarbon Sector Act) which defines the minimum amount of biofuel that should be incorporated into transport

fuels. The target was 1.9 % content by the end of 2008, 3.4 % by 2009 and 5.83% by 2010. However, the 2008 target was not made mandatory.

This section provides a picture of the Spanish biofuels sector with information about the current situation and the changes that are to be expected in the near future. Owing to the fast changing regulatory and market situation, the information offered by official institutions has been updated with that published by key organizations like the Asociación de Productores de Energías Renovables- APPA (Association of Small Producers of Renewable Energies), Biodiesel Spain and specialized media.

4.3.1 Bioethanol.

Spain is the top producer of bioethanol in Europe, with four plants operating in its national territory providing a total capacity of 445,000 t/year. However, owing to low national demand, the production in 2007 was estimated at only 284,000 t, most of which was exported to central Europe. This ethanol is produced primarily from wheat and barley, which are extensively grown in Spain. Residues derived from the production and processing of wine are also employed at a smaller scale.

Abengoa Bioenergia is first producer of bioethanol in Europe and fifth in the US. It currently operates three plants in Spain, four in the US and two more in France and the Netherlands. The three plants in Spanish territory include:

- Biocarburantes de Castilla y León is a joint venture between Abengoa Bioenergía and Ebro Puleva. The plant is located in Babilafuente (Salamanca), has been in operation since 2006 and has a production capacity of 160,000 t/year.

- Bioetanol Galicia located in Curtis (La Coruña), the plant opened in 2002 with capacity to produce 140,000 t/year of bioethanol.

- Ecocarburantes Españoles is located in Cartagena (Murcia) and started production in 2000 with capacity to produce 120,000 t/year.

A smaller plant co-owned by Acciona Energía and Uriel Inversiones started operations in 2006 in Alcazar de San Juan (Ciudad Real) with a capacity of 26,000 t/year.
Three more bioethanol plants are under construction in Zamora (145,000 t/year), Cantabria (126,000 t/year) and Badajoz (110,000 t/year), and several joint ventures have announced their intentions to build some in the future (for more information, see http://www.biodieselspain.com/plantas_listado.php)

As discussed above, some of these plants have been going through difficulties due to low national demand and had to reduce production or close for a period of time. This has been the case of Biocarburantes de Castilla y León (BCyC) which has remained closed between September 2007 and July 2008.

4.3.2 Biodiesel.

In 2007, Spain had 24 biodiesel plants in operation with capacity to generate 815,000 t/year. However, the total production during this year was only 147,000 t, 18 % of its capacity (MITYC, 2008). Two thirds of this production was exported to European markets. During that year, Spain also imported 150,000 t of biodiesel, primarily from US. Imports are favored by the high €/US$ exchange rate and also by the heavy subsidies applied to biodiesel production in the US (up to 200 € / t).

These figures are changing rapidly and the latest information from Biodiesel Spain (http://www.biodieselspain.com/) indicate the existence of 27 biodiesel plants in operation, 26 more plants under construction and 22 in project. The opening of all these new plants will increase the production capacity of the country 5 times.

Raw materials used for production vary depending on plant size and location. Smaller capacity plants tend to use recycled secondhand oil collected from restaurants and catering companies. The larger plants use virgin oils, mostly from soybean, sunflower, rapeseed and palm oil. Most of this soybean oil is imported from the US and the palm oil from Asia.

A typical example of a biodiesel company is Combustibles Ecológicos Biotel SL, which has a production facility in Barajas de Melo (Cuenca). The plant was originally designed and used by the Domecq Group for the production of whiskey. Bought by the Tello Group, it was adapted in 2002 for the production of biodiesel. A total of eight stirred tanks provide the plant a production capacity of 150,000 t/year.

5 CONCLUSIONS

Production of renewable energies is growing rapidly in Spain owing to the coming into effect of regulations derived from the *Plan de Energías Renovables 2005-2010* (Renewable Energies Plan). This Plan set very ambitious objectives for 2010 which relied primarily on the development of wind and biomass derived energy, including biofuels.

Growth in wind energy and photovoltaic generation has been significant in the last few years, situating Spain as one of the leaders in the development and application of these technologies. In contrast, progress in the biofuel and biomass sectors has been much slower than expected owing to the late coming into force of biofuels legislation and the limited success of the biomass power plants. As a result, a great deal of pressure and increased activity is expected in the next few years.

Spain has already developed a large capacity for the production of biofuels over the last few years and a larger number of plants are expected for the next few years. However, these plants have been working at a low capacity, waiting for a higher national demand. The next few years will be a period of substantial growth, with a great deal of instability provoked by market adjustments, and significant opportunities.

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Korean biofuels: the current status and perspectives

Jae Yeon Park, Byoung-In Sang, and Yun-Chul Chung*

Center for Environment Technology Research, Korea Institute of Science and Technology

*** Corresponding author: ychung@kist.re.kr**

Abstract

To become a nation with the sustainable growth, Korea has devoted its efforts to developing renewable energy, with a vision of “low-carbon and green growth.” Biofuels are a key alternative before ‘hydrogen-based economy’ will come in transportation. Biodiesel is the first biofuel to be commercialized in Korea, and efforts have been made to increase its usage. Bioethanol may present another option, and commercialization is about to begin. To prepare for the future, biobutanol and biohydrogen are being studied in several research groups, and cellulosic ethanol is an important upcoming research topic. With the cooperation of the government, companies, and researchers, Korea is working toward becoming an energy-independent nation.

Introduction

As the growing concern for global warming has gained social and political attention worldwide, the development of renewable energy sources has become an urgent need. Although the Republic of Korea belongs to the list of non-Annex I parties in the Kyoto protocol, Korea will probably be included in the Annex I parties in the following post-Kyoto protocol, due to its large CO_2 emission amount (ranked 9th worldwide) and its increment rate (ranked 1st in OECD countries). Therefore, it is urgent that Korea develop available carbon-neutral energy and/or renewable energy sources. In addition, in 2008, President Lee Myung-Bak declared his vision of “low-carbon, green growth” for the nation’s economic development during the next decade, which highlights the importance of the development of renewable energy [1].

The supply of renewable energy in Korea is 2.1% of the primary energy consumption, and most of this energy originates from waste and hydro-electric (90.7%, 2007). Bioenergy accounts for only 6.6% of the renewable energy, although its use has increased rapidly, as shown in Table 1 [2].

Table 1. Status of renewable energy sources in Korea over the past eight years.

	2000	2001	2002	2003	2004	2005	2006	2007
Solar	41.7	37.2	34.8	32.9	36.1	34.7	33.0	29.4
Photovoltaic	1.3	1.5	1.8	1.9	2.5	3.6	7.8	17.8
Biomass	82.0	82.5	116.8	131.1	135.0	181.3	274.5	382.5
Waste	1,977	2,308	2,732	3,039	3,313	3,705	3,975	4,319
Hydro-electric	20.5	20.9	27.6	1,225	1,082	918	867	908
Other (wind power, geothermal)	4.7	3.1	3.8	6.6	13.2	35.6	67.6	107.3
Total	2,127	2,453	2,917	4,437	4,582	4,879	5,225	5,764

(Energy info 2008) [2]

However, bioenergy, especially biofuel, is the only renewable fuel that can replace the current fossil-based fuel used in transportation, because the current infra-structure can be utilized without severe changes. Thus, biofuel probably represents the only alternate resource available until a ‘hydrogen-based economy’ is realized. Worldwide, about 27% of primary energy is used for transportation, and this rate is growing rapidly [3]; in Korea, 20.8% of energy was used for transportation in 2007 [2]. Because Korea’s oil supply is imported, it is also important to develop an alternate energy source to achieve energy independence and energy security. Table 2 shows the import of crude oil over the past eight years.

TABLE 1. KOREAN OIL IMPORT FOR THE PAST EIGHT YEARS

	2000	2001	2002	2003	2004	2005	2006	2007
Import (M$)	25,227	21,368	19,200	23,082	29,917	42,606	55,865	60,324
Amount (Mbbl)	894	859	791	805	826	843	889	873
Unit cost ($/bbl)	28.2	24.9	24.2	28.7	36.2	50.4	62.8	69.3

(www.kita.net)

Korea promoted a nationwide renewable energy project in 1987, by establishing 'the law for the promotion of development for alternative energy' that preceded the 'United Nations framework convention on climate change' of 1992. After a few amendments were made to the law, the full text was finally amended to 'the law for the development, usage, and the promotion of new and renewable energies' in Dec. 2004, for the commercialization and industrialization of renewable energy.

In biofuel policies and support in Korea, the supply is being focused on first, rather than the development of new technology, because more core technologies have been developed as compared to solar, wind, and hydrogen fuel cell technologies. There are many on-going research plans and technologies, but in general, efforts are being concentrated on spreading the usage and addressing the needs of the industry, rather than focusing on international competition [4]. The level of Korean biofuel technology is thought to be roughly 60-90% of that of other developed countries [5]. Enzymatic and fermentation processes are at a high level of development, but the infra-structure and resource-related technologies are not well advanced.

Biodiesel

Biodiesel is the only commercialized biofuel in Korea, and biodiesel-blended diesel (5%, BD5) is supplied at all gas stations, which is a unique case worldwide [5]. Research in this area began only ten years ago with a few groups, but the commercialization of this resource was rapidly realized. From 2002 to 2006, the biodiesel production increased from 977 kL to 15,500 kL by the exhibition project of biodiesel. During that period, BD20 was supplied to customers in assigned oil stations. Following that project, biodiesel was provided to all diesel vehicles. The quality standard was revised several times, considering environmental effects and setting up the utilization basis of biodiesel. Furthermore, tax support was provided to the customers according to 'the act for oil and alternative fuels' to promote the application. Although BD20 was tested in an exhibition project, it was revealed that the tested BD20 sometimes caused solidification, resulting in fouling of the filter and ignition problems [6]. Although the current technology has solved these problems, BD5 instead of BD20 is supplied at most stations, and BD 20 is only supplied to vehicles such as busses, trucks, and, construction machinery vehicles of companies that are equipped with oiling equipment and self-maintenance facilities. There are only 23 qualified companies for BD20, and the proportion of BD20 usage is very small, ca. 0.1% of the

TABLE 2. BIODIESEL STANDARDS IN KOREA

Biodiesel standards (Unit)	BD100	BD20	BD5
Ester content (wt %)	96.5 min	20 ± 3	5 max
Density 15□	860-900	815-855	815-855
Viscosity 40□ (mm^2/s)	1.9-5.0	1.9-5.5	1.9-5.5
Distillation 90% (□)	-	360 max	360 max
Flash point (□)	120 min	40 min	40 min
CCR 100% (% mass)	0.1 max	-	-
Carbon residue, 10% dist. Residue (% mass)	-	0.15 max	0.15 max
Cold filter-plugging point (□)	-	Summer : 0 Winter : -17.5	Summer : 0 Winter : -17.5
Sulfur (mg/kg)	10 max	30 max	30 max
Oxid ash (% mass)	0.01 max	0.01 max	0.01 max
Acid value (mg KOH/g)	0.5 max	0.1 max	0.06 max
Oxidation stability (hrs; 110□)	6 min	-	-
Cetane no.	-	45 min	45 min
Total glycerol (% mass)	0.24 max	-	-
Gp I metals (Na, K)	5 max	-	-
Gp II metals (Ca, Mg)	5 max	-	-
Phosphorus (mg/kg)	10 max	-	-
Methanol (% mass)	0.2 max	-	-
Water (mg/kg)	500 max	200 max	200 max
Cu corrosion max (3 h/50□)	1 max	1 max (100□)	1 max (100□)
Lubricity (μm at 60□)	460 max	460 max	460 max

total biodiesel production. Although BD5 was chosen as the standard, the mixing ratio of biodiesel began at 0.5% in 2006 and was then changed to 1.5% at the beginning of 2009.
When biodiesel was first supplied in Korea (2006), there were four registered companies, and the number increased to twenty during next year. Because the two main resources of biodiesel in Korea are soybean oil and waste edible oil, an abrupt increase in grain price (Agflation) and its over-production, as compared to the consumption demand, caused half of the companies to suspend production. Only nine companies currently act as suppliers to the oil companies [7]. The production processes involve mostly batch-type reactors, and three companies are using modified continuous processes. The total production capacity was announced at ca. 600,000 kL/year in 2007, but the actual capacity and quality of the product need to be carefully assessed.
The specification of the biodiesel was first made in 2002 based on ASTM of the USA, but it has been revised several times. The current standards are shown in Table 3. Because pouring and

filter plugging have been considered to be the main problems in the pre-test, a CFPP (cold filter-plugging point) was introduced. The iodine number was removed because soybean oil is the main resource in Korea. Oxidation stability was added to the list, in order to prevent any engine problems.

To expand the usage of biodiesel, the resource-importing nation and the resource itself must be diversified. Since the resource cost accounts for 70% of the total cost, the success of the biodiesel project depends on the attainment of resources. Currently, the whole soybean oil that is utilized in biodiesel production is imported from the USA. One company can produce biodiesel from waste-frying oil, and one company can produce it from palm oil [8]. This may cause safety problems, and furthermore, the national market is vulnerable to changes in the grain cost. Jatropha and palm oil can be alternative resources, but most farms in southern Asia have been occupied by companies from developed countries in Europe and/or Japan. In addition, the high viscosity and poor fluidity of these tropical oils at low temperature need to be improved before they are used [9]. Since many biodiesel companies in Korea are medium sized, there may be some limitations to promoting the long-term procurement of raw materials, although some companies have acquired successful contracts. As in the development of oil fields, the government is considering the exploration of biodiesel oil fields in plantations in Central and South America and in other possible plantation areas in southern Asia. Rapeseed oil, which is the main resource in Europe, can be cultivated in Korea, and this resource has been promoted by the Ministry for Food, Agriculture, Forestry, and Fisheries. Although the analysis of the production cost of biodiesel from rapeseed oil in Korea revealed a higher price than that of EU, the maximum cultivated rapeseed can replace over 5% of the total fuel consumption [9]. Therefore, it could be beneficial to replace imported soybean oil with rapeseed oil by the tax support, considering the steady supply of the resource. Seaweed oil can be a good resource in the long-term consideration of supplies, and technology development related to seaweed mass culture and its production will be followed in the near future.

Since the biodiesel content of BD5 is low, the biodiesel in BD5 is a kind of additive, but not truly renewable, fuel. BD20 and BD100, which represent truly renewable energy, are being used in Europe [6, 10]. To expand the usage of biodiesel, BD20 is being tested by several local governments [11], and application studies are being carried out. The government announced in the report for ‘the development strategy for green energy industry’ that they will shift the minimum biodiesel content from 1% to 3%, and this will become a mandate as of 2012 [11,12]. In the long-term plan, a 5% or higher portion of diesel will be replaced by biodiesel [4]. Even though the possible production capacity given by companies ranges from 600-800,000 kL, this amount represents only 5-7% of the total diesel consumption in Korea. Therefore, it is important to confirm the production capacity, raw materials procurement, and quality control before a decision on the expansion of biodiesel usage is made, so as not to impair this newly forming business.

Some projects that have been carried out by companies are worth mentioning. CTCbio Inc. has been studying the production of 3-HP (3-hydroxypropionic acid) from glycerol. The production of valuable chemicals from glycerol, or direct production of valuable chemicals other than glycerol during the biodiesel synthesis, is an important process that could reduce the cost of biodiesel [5]. Hence, other methods involving glycerol are being studied in several research groups as well.

KCI developed a method of transferring the fatty acid of rapeseed to various fatty acid amines, and this company is developing cultivation methods, fatty acid production techniques, and other applications involving the rapeseed [5].

SK Chemical, a large company in Korea that has entered the renewable energy market, set up a joint company Guilin SK Zhongning Bio Co. Ltd in China with the Chinese government enterprise Zhejiang Zhongning Business Co. Ltd [13]. This joint company is the result of SK Chemical effort to obtain a steady supply of jatropha, and the production of jatropha will begin in a 2000-ha area in Guangxi province from 2010.

Nature & Environment Co., Ltd received a stock of the Indonesian company PT. AGB Energy to produce jatropha biodiesel, by leasing 9000 ha in a northern region for a maximum of seventy years [14]. These stocks were handled from ICM (not a USA company), a parent company of the Korean biodiesel company BDK. ICM created a joint venture company in Hainan Island, China to obtain jatropha [5, 15].

BNDenergy has also tried to obtain a steady resource by cooperating with the Kolao group, which has a large plantation plan for jatropha in Laos [16].

Eco Solutions Co. Ltd created production companies in the Philippines (Eco Global Bio-oils) and in Malaysia (Global Bio-diesel), which use palm and jatropha oils, respectively [17, 18]. In addition, a biodiesel-selling contract from these companies was made with the international energy-trading company Masefield.

In the current Korean biodiesel market, there is a somewhat excessive competition, due to the over-establishment of the production companies whose capacities are greater than the current market size [19]. Major Korean oil companies have already selected companies for supplying biodiesel [7]. The remaining companies that were not chosen have no relevance in the market, except for the direct supply of BD20 to the few places that are able to use BD20. These unselected companies may suffer from resource shortages, worsening the financial conditions. This competition should end soon, and qualified and stable companies will survive. After this period, cheap and stable resources that are not related to food, such as energy crops, will guarantee prosperity for the companies.

Bioethanol

Bioethanol is not only the main source of drinking alcohol but is also a basic material for electronics, food, medical supplies, and cosmetics. In Korea, there are ten bioethanol-producing companies, and the production amount was 309 ML in 2006 [6]. Over 90% of the bioethanol is currently used for drinking alcohol. The first generation of bioethanol production technology is already fully developed, due to the technology related to alcohol. While most of the production technology used in current domestic factories involves batch-type processes, continuous operation technology might be needed in the near future, considering the amount of bioethanol required.

Studies of bioethanol began in the late 1980s, and many results regarding production technologies on a lab scale were developed. A pilot-scale bioethanol production plant from starch was built in 1992, and twenty exhibition cars fueled by 10% bioethanol were operated in Pusan, 1996 [6]. However, bioethanol had not been systematically tested as a fuel on a large scale, and this presented an obstacle to commercialization. A demonstrative project for transportation and vehicle adaptability testing was carried out from 2006 to 2008. The project named the 'actual assessment to introduce bioethanol blended fuel,' aimed at evaluating any possible transportation and storage problems, was carried out by the Korea Energy Management Cooperation and the Korea Institute of Petroleum Quality [20]. Changhae Ethanol supplied the bioethanol and four major fuel companies (SK Energy, GS Caltex, S-OIL, and Hyundai Oilbank) took part by offering one gas station each [21]. The research studying the primary concerns of phase separation and the corrosion of components revealed that a bioethanol content greater than 3%, such as that of E3 and E5, could avoid separation problems under careful management, and most of the mechanical parts remained untainted during the test period, although the flexibility of the rubber parts (sealing) decreased. Actual long-term driving tests are still needed to confirm the durability of the accessory parts. Pre-mixed bioethanol-gasoline fuel has been proved to be stable during repeated shipment and pumping, but the replacement of infra-structures such as pipelines, tanks, and gas pump hoses, together with routine checking systems, is needed to supply the blended fuel to the customers. The estimated cost for these changes is substantial, reaching 700 billion won if the entire infra-structure was to be changed. No conclusions were determined with regard to vehicle stability, due to the short test period, but this assessment project will be continued by the local government [21, 22, 23]. The quality of the blended fuel was satisfactory, but high vapor pressures could induce an ignition problem at high temperatures and could increase the 'evaporative emission,' which may cause smog [20].

Since there are precipitation differences in each region and since a large fund for the replacement of some infra-structures in the oil stations is needed, the introduction of ETBE rather than bioethanol is appealing [22]. ETBE is an alternative to MTBE, which causes soil and underground water contamination once it is leaked into the environment. Bio-ETBE, like ETBE, increases the octane number of a fuel, has low water solubility, thus preventing phase separation, and has a low vapor pressure, preventing the formation of photochemical smog. Since E3 and E5 are additive resources and require large funds, Bio-ETBE could be a more stable and economic additive than bioethanol, considering the present circumstances in Korea. The Korea Institute of Petroleum Quality is testing the feasibility of Bio-ETBE for the replacement of MTBE and bioethanol, the quality of a blended fuel, and its environmental effects.

The securement of raw materials is an important issue to consider. Bioethanol is expected to have a cost one and a half times greater than that of petroleum gasoline, as shown by an analysis of the production cost when using domestic fermentable resources, revealing that international cooperation in importing resources will be necessary until the second generation of bioethanol technology (cellulosic ethanol) can be commercialized. A few companies have prepared stable resource-supplying areas, occasionally with production factories, and have made plans for exporting ethanol to foreign countries until bioethanol can be utilized as a fuel in Korea.

Changhae Ethanol made a contract with Papua New Guinea for leasing 20,000 ha free for forty years in order to cultivate cassava. By hiring a certain portion of native employees and by helping the development of the rural community, this company is fully supported by the Papua New Guinea government. [5, 24, 25] This is a successful example of exporting technology to developing countries, which could be a big market for the next twenty years.

Odicorp Co. Ltd. built a company PT. CBI in Indonesia, by co-investing with its subsidiary company CSM Co. Ltd., and made a contract with the Indonesian government to lease a cassava plantation of 200,000 ha for a maximum of 55 years in 2006. This company also made a contract with PT PGR 1(Pabrik Gula Rajawali 1), a subsidiary company of the largest government enterprise PT RNI (Rajawali Nusantara Indonesia), for the construction of a bioethanol factory, and the construction began in 2008 [26, 27].

In 1999, MH Ethanol leased 8000 ha in Cambodia for the cultivation of tapioca, which is the first case of a long-term land lease in Korea. This company recently exported bioethanol produced in Cambodia to the Swiss company Bauche, which is also the first export of Asian bioethanol to EU [24, 28].

EP Energy Co. Ltd. contracted MOU with the Indonesian government enterprise PT Perkebunan Nusantara VIII (PTPN VIII) for the plantation and supply of cassava in Indonesia [29]. The factory construction began in 2008, and they plan to produce bioethanol in 2010.

Although the production costs of bioethanol from these companies are still higher than those of Brazilian bioethanol, the increasing demand of bioethanol worldwide, arising from transportation costs, will most likely give some competitive power to southern Asian bioethanol.

Future perspectives and next-generation biofuels

The Ministry of Knowledge Economy selected 100 projects for a ‘Green Ocean’ plan [30]. Biofuel production was included in this list of projects. According to that plan, mass production and commercialization will be completed by 2012, and 20% of the domestic gasoline needs and 7% of the domestic chemical needs will be supplied by biofuels. Moreover, Korea’s status of an energy-importing nation can be changed to an energy-exporting nation by the biofuel project [30]. Algae-originated bioethanol is expected to play a role in achieving this objective. In addition, BD30 produced by biological catalysts, biobutanol production technology, and biohydrogen production technology represents a biofuel-related project included in this plan.
In long-term prospects, cellulosic ethanol is a key issue. A 20-L/day scale process has been built, and pre-treatment and cellulose production technology have also been tested by some research groups [6]. As for commercialization, the government has started to study this technology deeply and cooperatively by considering the full-scale production, and later, the collection, treatment, and transportation of resources will be studied.

Biobutanol has been suggested as an alternative fuel of bioethanol that is able to reduce some disadvantages such as phase separation, energy density, and corrosive problems. Worldwide, the technology level is still far from the commercialization of biobutanol technology, but a few researchers and companies in Korea try to produce biobutanol economically as a future biofuel.

Biogases such as biohydrogen and biomethane are known as the third generation of biofuels. Fuel cell technology combined with biohydrogen could solve the future energy crisis, but the gap between these two technologies makes this process unclear with regard to commercialization [31]. Biogas technology in Korea has developed considerably, especially in the practices of reusing organic waste by using anaerobic digestion and gas gathering from landfill sites [32]. Most technologies are in the proving state. However, biogas, especially biohydrogen, as a fuel will be promoted by thermal cracking of biomass and/or biological catalysts in the near future, and related technologies and systems are being prepared.

The Korean biofuel market is small but is growing rapidly, due to cooperation between the government, companies, and research groups, which will give Korea a new chance to become a clean-energy nation.

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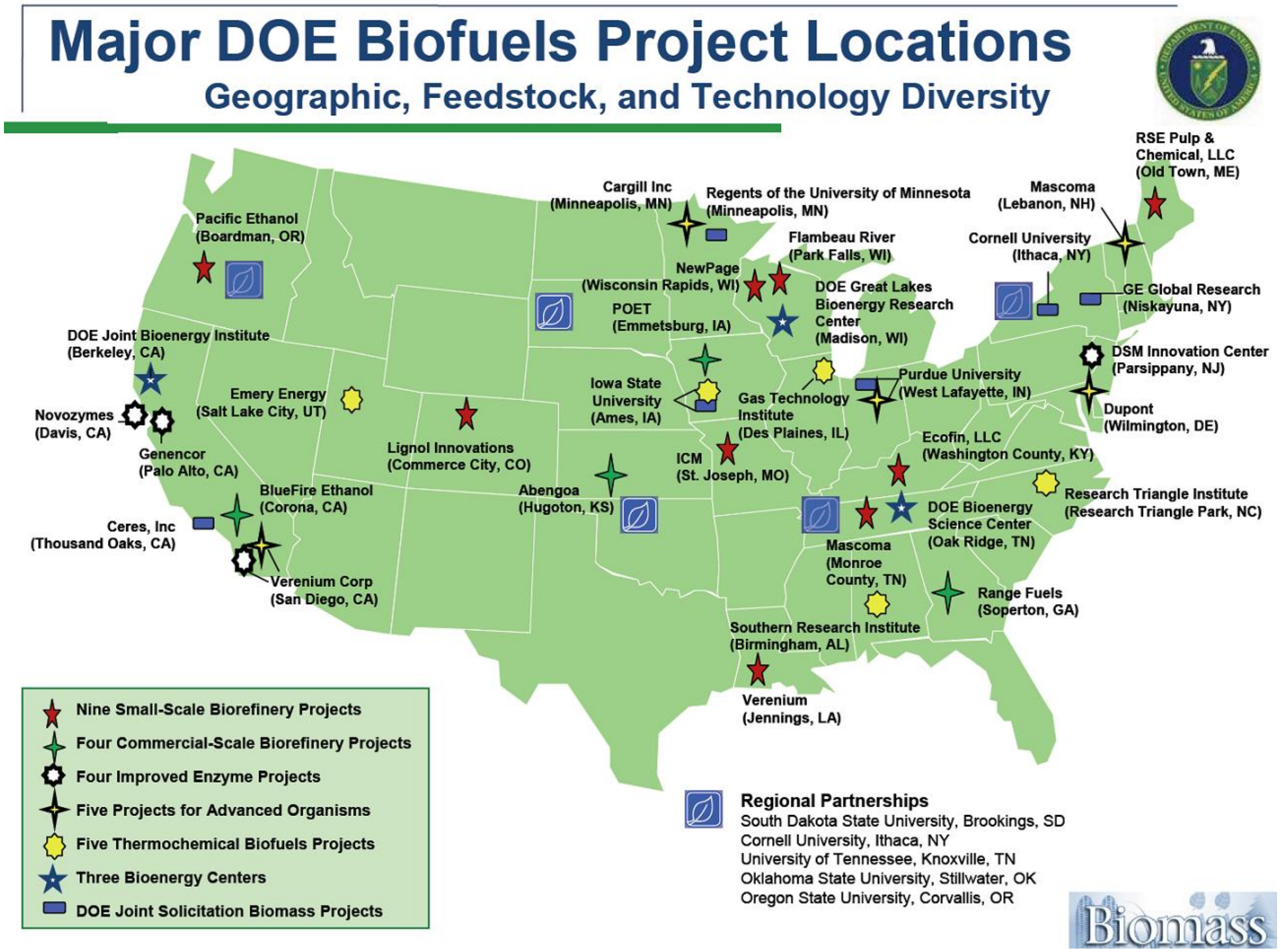
Biofuels in the USA



(Courtesy US DOE)

The above map is a snapshot of major projects that are underway in the U.S. since 2006. These also include commercial-scale biorefinery projects that are cost-shared between DOE and industry. In basic research, the U.S. DOE has made substantial investment ($ 375 million over five years) by setting up three bioenergy centers that focus on developing the improved "Biochemical" pathway to process biomass with emphasis on *lignocellulose* to biofuels. These bio centers are now augmented by the Energy Frontier Research Centers (EFRCs') (http://www.er.doe.gov/bes/EFRC.html) that were announced in April 2009. It is hoped that a combination of research/pilot/demonstration scale investment will produce commercially viable technologies in the near future.

Since the information on the projects located on the map is readily available from various DOE and other sources, no further details of these projects is discussed here. Rather, a few U.S participants reflect on other biofuel activities by non-DOE agencies. These are:

1. "Biofuels from the Military Perspective", by Richard Coffin, Naval Research Laboratory.

2. Center for Bioenergy Development (C-BERD) (www.bioenergynow.org), a National Science Foundation funded center through the Industry/University Cooperative Research Center (I/UCRC) program, by Dr. Duane Abata, South Dakota School of Mines and Technology. The Center is a consortium of 6 universities (South Dakota School of Mines and Technology, Kansas State University, South Dakota State University, Stony Brook University, University of Hawaii, and North Carolina State University) and is supported by over 30 bioenergy companies.

A brief description of these two examples is given below. Note that the research themes identified in the report: "*Breaking the Chemical and Engineering Barriers to Lignocellulosic Biofuels- Next Generation Hydrocarbon Biorefineries* (National Science Foundation (NSF)/ United States Department of Energy (U.S. DOE)/ American Chemical Society (ACS) Report, 2007)" form the basis of most of the funded research.

Biofuels and their Application in the Military

Richard B. Coffin
Naval Research Laboratory
Washington DC, 20375

E-mail: richard.coffin@nrl.navy.mil

Overview

With photosynthesis sun light energy is converted to chemical energy in plants. There is a strong global effort in converting this energy to liquid organic fuels (Brown, 2003). While the current economy does not favor the development of biofuels, environmental impacts, national security and support of agriculture does set a stage for the development. With the concerns for the human impact on climate change it is thought that production of biofuels can result in a lower CO_2 emission with assimilation, production, and subsequent return to CO_2. This approach is believed to reduce the CO_2 release to the atmosphere that is associated with refining and combustion of petroleum reserves. There is global realization that petroleum reserves have a strong influence on national securities. This fact has lead Japan, currently importing 96% of the national energy needs, to developing new energyl sources. The United States is predicted to grow to 64% petroleum import by 2020 (Brown, 2003). The economic impact of petroleum limitations and expanded imports has been shown to result in international conflicts. There has also been a change in the farming market with biofuel development. The transition of agriculture to support a fuel market has resulted in the sharp increase of food prices. While all of these factors supports the need for biofuel development, this approach to fuel does not meet all of the US military needs. Biofuels have a lower energy that reduces the support for military logistics. In additions this fuel, with long storage times, has been shown to lower energy capacity. The development of biofuels needs careful consideration and is likely to vary between different nations.

The development of biofuels as a significant future energy requires addressing several major challenges. First there is the simply transport of this fuel feed stock. While the different sources can be collected and stored, there is a challenge and large expense in shipping this material for the fuel production. The initial processing of feedstock into small process able material can consume a significant amount of the total production energy. Other issues related to the processing of biofuel feedstock include the harvested biomass moisture and the lowered fuel energy. Harvested feedstock may have up to 50% moisture content and field drying may only reduce the moisture content to 20% (Brown, 2003). The energy capability of the biofuels is reduce in a range of 15% to 50% as a function of the crop energy content and the oxygenation of the fuel. A thorough evaluation of biofuel as an alternative energy needs to consider the feedstock energy content, composition of the fuels produced, and efficiency of the processing technologies.

Potential Biofuel Feedstock

Forests, agriculture, algal and waste materials can be sourced for biofuel production. Biomass wastes production in the US is estimated to be 280 million tons y^{-1}, while the other total agricultural biomass is estimated to be 46 million tons y^{-1} (National Research Council, 2000). The selection between these feedstocks needs to consider the potential energy extraction from the biomass and the crop production density. A key issue for consideration is the production time relative to the biomass that is acquired. Sugar beets and switchgrass are harvested annually while hybrid poplar and willow trees require 3 to 10 years. Another issue with selection of the feedstock is the efficiency of using the total biomass that is produced. Alfalfa leaves with high protein can be processed to feed livestock and the fibrous stems can be processed as a fuel. In contrast the milling of sugar cane has a high biomass waste during the extraction of sugar for fermentation and the residual of bagasse.

Key feedstocks contain oil, starch, sugar and lignocellulose. The agriculture of the feed stock needs to focus on the high energy content of lignocellulose. The lignocellulose is contained in herbaceous crops and short-rotation wood crops. The herbaceous crops that have high levels of lignocellulose are thick stemmed grasses such at sugarcane, napiergrass, corn, and sorghum. The harvesting of these thick stemmed grasses is labor intensive. Thin stemmed grasses such as fescue, switchgrass can be harvested with the conventional farming equipment. Potential feedstock woody crops include hardwood and softwood. While poplar, willows, silver maple, sweetgum, sycamore and eucalyptus the most promising appear to be the polar and eucalyptus with growth rates averaging between 10 and 17 Mg ha-1 y-1 (Brown, 2003). There is a large range in the annual yield of these crops from 1,300 to 55,000 kg ha-1 (Brown, 2003; Wayman and Parekh, 1990). The high annual yields are seen with the sugar cane and sweet sorghum. Low yields are the corn and wheat.

A new frontier in the biofuel production focuses on algae as the feedstock. It has been realized that algal production technology is up to 10 times higher production of fuel than the other crops (Waltz, 2009). This farming can be run in salt and fresh water, and the crop can be fueled with sewage and municipal wastes. Through 50 years of development, lead by DOE at the National Renewable Energy Lab between 1978 and 1996, technology developed for genetic transformation in the algae that resulted in the enhanced cellular oil production. Estimates of the oil production from algae are currently at 6,000 gallons ac^{-1} y^{-1}; substantially greater than the other biofuels which range from 43 to 641 gallons ac^{-1} yr^{-1} (Waltz, 2009).

A large focus on the development of biofuels addresses genetic selection to improve yields of compounds needed for the fuel production, resistance to pests, and alter selective climate growth. In today's genetic technology there is capability to isolate key genes and use promoter and termination sequences that insert genes needs to advance these needs in the biofuel technology. Developing research on genetic insertions includes viral and bacterial transduction, electroporation using high electrical potential, microprojectile bombardment with micron-sized particles of tungsten coated with DNA sequences, and microinjection through microcapillaries. This technology has potential to lead to the development of plant factories in all lines of the biofuel feedstock production.

Fuel Composition

In the current fuel market there is a large range of transportation fuels that biofuel development can support. Currently the transportation engine fuel needs are for diesel and jet fuel and gasoline. The development of these fuels for each engine category needs to consider the combustion energy yield, efficiency in the production technology, and long term storage capability. Typically gasoline is composed of 4 to 12 carbon atoms with boiling point ranging 25-225°C (Brown, 2003). The variation in diesel fuel it a mixture of hydrocarbons that are less volatile with a higher viscosity. Jet fuel is a kerosene derivative with more wide boiling range, with more rapid evaporation.

The development of biofuels primarily focuses on ethanol and methanol for spark engine ignition and biodiesel compression engine combustion. There needs to be consideration of the energy provided by these fuels. Ethanol is estimated to be 99% of the biofuel use in the US (Davis and Diegel, 2004). Ethanol provides only 66% of the heating capacity of gasoline. However, increased engine efficiency for ethanol allows engines to operate with a higher compression ratio, resulting in more fuel efficiency and result in a driving range of 80% that of gasoline (Brown, 2003). Another issue that needs careful consideration with the ethanol is water contamination with the fuel storage. This is not being addressed and these fuels are not subject to long term storage (Brown, 2003). Methanol is similar to the properties of ethanol with much lower heating capacity and stability in storage. For development of methanol as a transportation fuel there needs to be a resolution of economic and environmental issues.

Biodiesel fuel is comprised of fatty acids with high viscosity and low volatility that have higher viscosity and less volatility than the petroleum based diesel fuels. The conversion of triglycerides to methyl and ethyl esters of fatty acids results in less fouling of engine valves and higher combustion performance. The combustion properties of the biodiesels are similar to petroleum sourced diesel fuels. The only issue for the use of biodiesel has been the need for frequent oil changes to solve build-up of wastes in the engine crankcase. Biodiesel fuels are developing as a beneficial energy resource but need to be considered for the net energy loss and biodegradation with long term storage.

Production

The production of biofuels is fermentation of sugars crops such as a variety of fruits, sugar cane, sugar beets and sweet sorghum to ethanol and starch and inulin crops such as corn wheat and barley. Ethanol yields from these feedstocks range from 63 to 370 L t^{-1} (Klass, 1998) with low production in fruits and higher production in the corn, and wheat. Ethanol production is approximately 1.0 billion gal y^{-1} with one third of the production from dry milling plants and two thirds from wet milling (Brown, 2003). Feed stock dry milling products are slurried with water to form a paste that is fermented to ethanol. Wet milling provides the separation of carbohydrates, lipids, protein rich gluten, and fiber that allows for a more efficient fermentation. There is also potential for conversion of lignocellulose feedstocks to sugar for fermentation. Processing for this method requires pretreatment to increase the lignocellulose surface area that is up to 33% of the total processing costs (Brown, 2003). The subsequent step in the processing is hydrolysis with sulfuric and hydrocholoric acids and acid neutralization with limestone. This step in the production results in 40,000 tons of wet gypsum for a 20 million L yr^{-1} plant (Brown, 2003). The final steps in the processing are fermentation and distillation for a final maximum total energy consumption in the processing of 11.1 to 12.5 MJ l^{-1} of ethanol. This technology requires more energy in the production than provided in the product (Brown, 2003).

Lipids include energy rich terpenes and esters of fatty acids that can be obtained through a relative simple process. Pressing of seeds is used to extract the oil from seeds with high oil content or a solvent extraction in seeds with lower content. The triglycerides obtained in this process result in engine coking and require transeterification where ethanol and methanol are catalyzed to react with triglycerides for methanol and ethanol production.

Another option for acquiring energy in feedstock is pyrolysis for decomposition to the fuel. In a temperature range of 400-600°C, at atmospheric pressure, over 0.5 to 2 seconds liquid yields of 78% can be obtained and this extraction contains 560 L t^{-1} oil (Brown, 2003). This material can be used for fuel in turbines or modified diesel engines, but is a lower quality than Bunker C heavy fuel oil. Direct or indirect liquefication provide a more clean production of the fuels. Direct liquefication is conducted near 200 atm pressure at temperature under 350°C. Indirect liquefication, used to produce fuel by gasification of organic matter to H_2 and CO_2 and then followed with synthesis of ethanol or methanol through synfuel production. With the production of these lower molecular weight building blocks higher molecular weight fuels can be synthesized.

Biofuels from a Military Perspective

There is a wide range of perspective for the use of biofuels to support US military missions. This range of opinions results from the diversity of military goals. For the general fuel needs in shipping and transport a lower energy will not impact the mission focus. However, fuel is a primary logistical demand on a battlefield. With military activity in Iraq the cost of one gallon of fuel is estimated to be $300 USD (Hardy et al., 2003). The production of biofuels at a site have potential to provide fuels at a reduced cost. There have been applications of the biofuel production demonstrated with food wastes used for the feedstock.

While there is some potential for military fuel application, there can be a strong negative impact. During recent workshops there have been statements for biofuels not meeting the all of the military requirements (Hardy et al., 2003; Coffin, 2006; Schifler, 2008). Biofuels are recognized as having up to 15% lower energy. This reduction of energy in energy has potential to lower the military capability for the strike targets and tactical loading during missions. New program development has focused on addressing the potential reduced energy in biofuels with non carbon additive such as boron and aluminum and higher energy carbon structure compounds (Coffin, 2006). The theoretical energy potential in a boron loading is a 30% enhancement. While boron was not a stable rocket fuel during the 1950's, new advances in nanotechnology has shown potential for gas turbine and diesel fuel energy increases. The issues of fuel degradation, elevated wear on the engine, and lower energy need to be considered for military missions. These issues are different and do not always coincide with private sector goals.

Conclusions

We are in the middle of a global carbon economy that is balanced by profits in the energy and deficits in the CO_2 production. There is a need for a thorough overview of the global carbon based fuel budget that is related to non carbon based fuel development. A general energy interpretation that addresses the potential energy in terms of kinetic and endothermic properties and enthalpy through the production to the final product is necessary for this interpretation. This evaluation also needs to be compared for the environmental impact of the fuel production. There is a CO_2 assimilation that concurs with the feed stock production. In a reversed position the processing can cause negative environmental impact in terms of soil erosion, and atmospheric and water pollution. This long term environmental impact may not be a constructive technology relative to the benefit to climate change with the lowered CO_2 fixation.

Recent overview of global carbon emission occurring with economic responses to higher prices on land use for fuel development suggest that the green house emissions could double over 30 years (Searchinger et al. 2008). This prediction supports biofuel development with wastes and desert algal ponds as the feedstock, because there is not a change of land use and emissions are reduced. In another recent study, it is suggested that a thorough environmental metrics is needed for an accurate carbon budget prediction with ethanol biofuel production and that new cellulosic technology will be required (Farrell et al. 2006).

Finally, there is a need to consider the market in new fuel development. There is a large difference in requirements between the commercial and military fuel demands. The energy and power density of commercial market fuels can be low while this will not meet military requirements. Military fuel volatility will need to remain low while it can be high in the commercial market if combustion system safeguards are maintained. Military fuel demands can over lap with the commercial market for general operations.

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Center for BioEnergy Research and Development (CBERD)

(www.bioenergynow.org)

Duane L. Abata
South Dakota School of Mines and Technology
Rapid City, South Dakota
U.S.A.
E-mail: duane.abata@sdsmt.edu

To date, bioprocessing at the commercial level has largely been based on *starch*-to-ethanol technology. To realistically meet the President's goals, technology is needed for conversion of *lignocellulosics and oil and fat resources* into fuels, chemicals, and biomaterials. In essence, the new biorefinery concept parallels the petroleum refinery, except that the feedstock will be abundant, renewable biomass (Figure 1).

Center for BioEnergy Research and Development, CBERD, is both a fundamental and applied research multi-university and multidiscipline center focused on all aspects of bioprocessing including feedstock agronomy and supply, feedstock breeding and genomics, bioprocessing microbes and enzymes, biomass processing, new platform technologies, and modeling and process lifecycle analysis. CBERD is a consortium of six universities throughout the United States funded jointly by industry, the National Science Foundation (NSF), and each of the academic institutions in CBERD. These academic institutions are South Dakota School of Mines and Technology (lead institution), the University of Hawaii, Kansas State University, Stony Brook University, North Carolina State University, and South Dakota State University. CBERD involves over one hundred members of the faculty and several hundred graduate students with a joint $100 million dollar investment in buildings, facilities and equipment dedicated to bioprocessing and chemical engineering.

The CBRD's focus will be on the sequential *process steps* critical for converting biomass into economically viable products. Our research foci are industry driven, an advantage for commercialization. Our industrial partners are committed to assisting us develop and commercialize lignocellulose conversion technology. The aforementioned reports and industrial members desires have provided the research and technology development framework for the CBERD I/UCRC. Analysis of these reports point to four major areas for focused R&D efforts to move lignocellulose based biorefining from the lab to the commercialization. These four areas are feedstock development, sugar platform, thermochemical platform, and biorefinery technology integration. The latter includes lifecycle analysis, energy analysis, economic analysis, process analysis, and environmental analysis. The CBERD I/UCRC team of universities and industry partners are moving forward in areas critical to achieving economical and sustainable conversion of biomass into biofuels and other biomaterials.

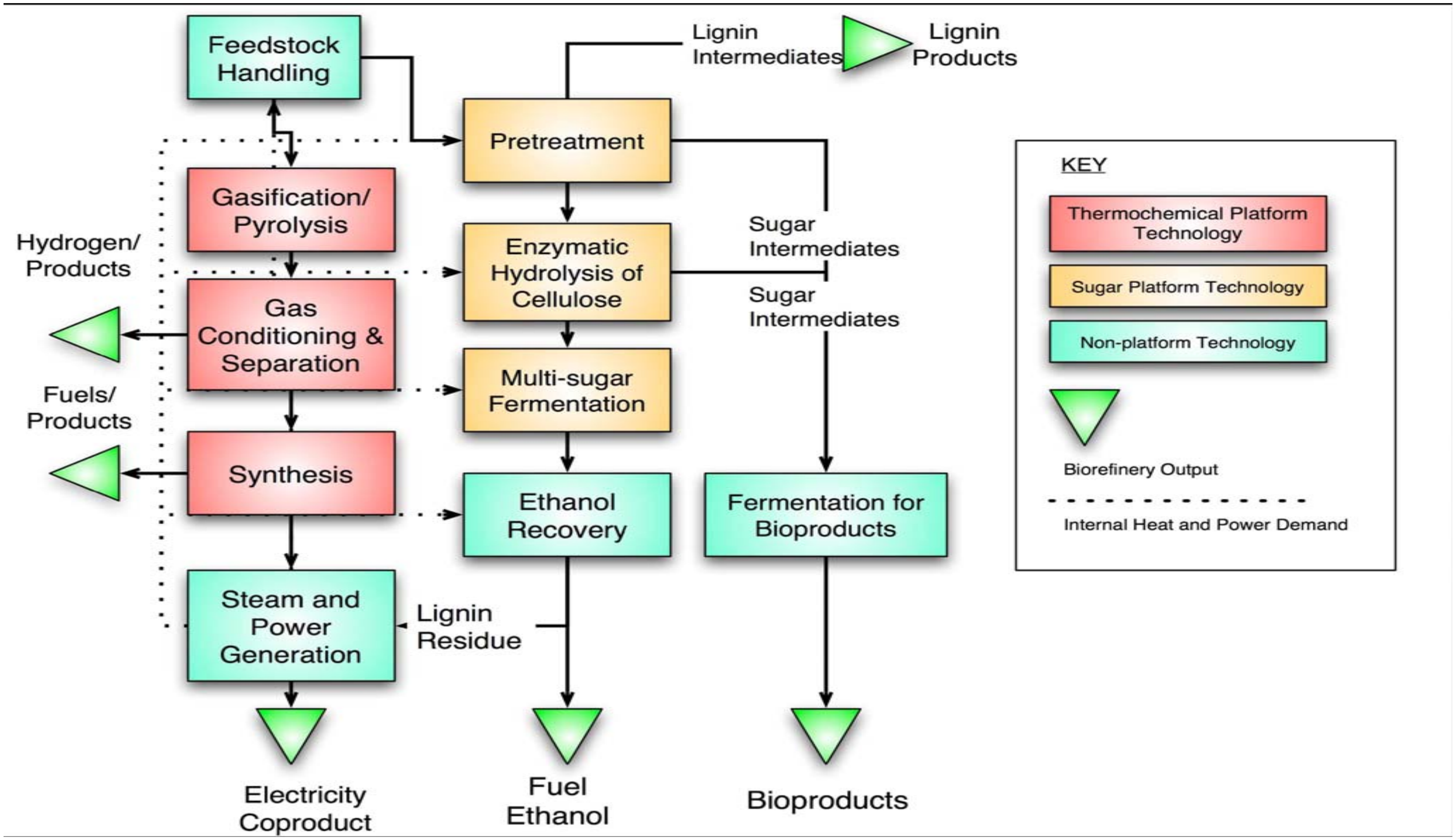

Figure 1. The “Biorefinery Concept

Table 1 is a map of each focus area to member universities with resident expertise. The CBERD I/UCRC universities are committed to pooling their expertise in a collaborative manner to address the industry directed research. This multi-institutional approach provides a mechanism to focus the human resources (faculty and students) who have specific and complementary expertise to address difficult and urgent research questions. This approach provides CBERD I/UCRC partners (university faculty and students and members) with a much richer research environment than would be available if any one of the partners were to pursue a research project on their own.

Table 1 Mapping of Focus Area to University.

	KSU	NCSU	SDSM&T	SDSU	SBU	U HI	KU
Feedstock: Agronomy Supply							
Feedstock: Breeding Genomics							
Microbial Engineering							
Biomass Processing							
Platform Technologies							
Modeling Process LCA							

CBERD has established an Industrial Advisory Board (IAB) that helps select projects that are then carried out within the Center. The teams consisting of faculty, graduate and undergraduate students work together on projects selected with the IAB input. The Center formally started operating in September 2008. For more information, please visit the website at: www.bioenergynow.org.

About
ECI

Engineering Conferences International (ECI) is the successor program to the United Engineering Foundation conferences program that was established in 1962 to provide an opportunity for the exploration of problems and issues of concern to engineers from many disciplines. ECI is a not-for-profit partnership between the Engineering Conferences Foundation and Polytechnic University.

The format of the weeklong research conference provides morning and late afternoon or evening sessions in which major presentations are made. Available time is included during the afternoons for ad hoc meetings, informal discussions, and/or recreation. This format is designed to enhance rapport among participants and promote dialogue on the development of the meeting. We believe the conferences have been instrumental in generating ideas and disseminating information to a greater extent than is possible through more conventional forums.

All participants are expected both to attend the entire conference and to contribute actively to the discussions. The recording of lectures and presentations is forbidden. As ECI conferences take place in an informal atmosphere, casual clothing is the usual attire.