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Project acronym: **Star-COLIBRI**

Project title:
Strategic Targets for 2020 –
Collaboration Initiative on Biorefineries

Instrument: **Specific Support Action**

Thematic Priority: Coordination and
support actions

D 2.3 Collection of information on biorefinery research funding and research organisations (projects)

– Task 2.3.2 Outside Europe –

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PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Wageningen UR – Food & Biobased Research

Version 12/04/10

Content

1 Introduction

1.1 Task description in DOW

In addition to European research information, this task will also provide an outlook on research into biorefineries in the US, Canada, Australia, China, India and South America. The results will be used for benchmarking or to indicate new opportunities. International initiatives and collaborations like the EC-US Task Force on biotechnology, Canada's Agricultural Bioproducts Innovation Program (ABIP) and the OECD working groups on biotechnology and Biofuels will be studied (A+F = Wageningen UR Food and Biobased Research).

1.2 Methodology

The most recent EU-funded Specific Support Action projects (Bioref-Integ, Biorefinery Euroview, Biopol and Sustoil) on biorefinery knowledge were taken as a starting point for data collection for this report. Furthermore, input was taken from the (country) reports of the IEA Task 42 Biorefinery, which is coordinated by A+F. Literature research was combined with a thorough scan of the web to find as much information as possible. This survey concentrated on finding basic information. No further analysis of the information has been made in this report, since this will be done in the next StarColibri tasks. For the US, Canada and Australia, the information was sent to the IEA Task 42 members of these countries to verify the information found. The information for Brazil was checked by the director of the Wageningen UR office for Latin America. This report describes all the information that could be found within the limited available time within Task 2.3.2 of StarColibri. Of course a survey like this can never be complete, since the amount of research organisations and their research topics is enormous. So if certain items are left blank in the text of a record, or if certain organisations are missing, this only means that no information could be found yet. However, that information could probably be obtained when the research organisation would be contacted in person, or when more time was available to find missing organisations.

1.3 Use of the collected data

The data that have been collected for this report need to be easily accessible in the other tasks of the StarColibri project. Therefore they will be entered later on in a WIKI-based database system developed in Task 2.2. This is the reason why the information is given in well defined standardized pieces (records). However, this document itself is also suitable for finding information by searching for key-words or following weblinks to obtain more detailed information.

2 Research outside Europe

2.1 Description of regions

The following regions/countries were studied:

- US
- Canada
- Australia
- Asia: China, India & Japan
- Brazil

2.2 Description of research funding programmes

Relevant aspects:

- Name of funding agency
- Name of funding programme
- Main goal/topic
- Time status (ongoing/planned, start & end date)
- Total budget
- Website/address
- Source & date information

The items per information record that are described above are more or less self explanatory. However, in the next section some further remarks are made that also hold for the items of the funding programmes.

2.3 Description of research organisations

Relevant aspects:

- Name of organisation(s)
- Main goal
- Type of Biorefinery (BR)
- Time status (ongoing/planned, start & end date)
- Total budget
- Website/address
- Source & date information

The references have been sorted by the name of the main participating organisation. The first intention of this survey was to collect information about individual projects. However, since detailed project information could not always be found, it was decided to list the organisations in this overview rather than the individual projects.

Only research organisations (sometimes with a pilot plants under a certain size) have been taken into account. So no companies or commercial demo plants as such that scale up proven

new technology were investigated. However, at these demo plants new research projects might emerge. If this is the case they will be included.

The item ‘Main goal’ describes the most important information, which is the relevant knowledge and expertise of the organisation. Not only ‘pure’ biorefinery research has been included, but also biorefinery related research. On the other hand e.g. dedicated research only on the production of biofuels has not been included. However, some overlap could not be prevented. In many cases the original text supplied by the organisation has been copied directly and unchanged into the main goal item. This was done to avoid misinterpretation of the original information. Often only the most important pieces of information were transferred to this document. Further information can be then found through the sources item.

If possible the ‘type of biorefinery’ (that was studied or where the described research could be applied) was determined based on the information found. It was classified as one of the following types (of which the first five are also described in StarColibri Deliverable 2.1):

- cereal biorefinery/ whole crop biorefinery;
- green biorefinery;
- oilseed biorefinery;
- lignocellulosic feedstock biorefinery;
- marine biorefinery;
- thermochemical pathway / syngas platform biorefinery.

It turned out that the ‘time status’ and ‘budget’ items were often difficult to find especially for organisations. So they were often left blank. Sometimes they were available for individual projects. The ‘website’ item specifies the main website of the organisation. This web address is given in full detail. The item ‘sources’ contains direct links to the original information. In the text these links are often described by the name of the organisation and some keywords about the content. However, they also contain the full description of the link in the underlying html-link.

2.4 Description of pilots

For pilots the following relevant aspects will be described:

- Name of organisation(s)
- Name of pilot
- Description
- Feedstock
- Products
- Type of Biorefinery (BR)
- Time status (ongoing/planned, start & end date)
- Total budget
- Website/address
- Source & date information

3 US

3.1 Introduction US

According to Wellisch (2009) strong drivers for biorefinery development in the US are energy security and rural economy (agriculture). The government and private sector are heavily investing in technology development. The focus is both on R&D and on scale-up (pilot, demo and pre-commercial) of biorefineries. About 1.1 B $US is being invested by US DOE. Dedicated feedstocks are being used, combined with genetic engineering. Technology focus is on the thermochemical platform biorefinery (both gasification and pyrolysis) and the biochemical platform for a variety of feedstocks. Products are mainly mixed alcohols, hydrocarbons (bio-HCs) and bioproducts. Finally attention is given to integration aspects and engineering issues (large facilities with economy of scale).

Figure 1 Map of US (source: www.mapsofworld.com/usa/usa-state-and-capital-map.html).

The US government is sending strong signals in the field of legislation, targets, standards and investments. Examples are:

- Energy Policy Act (EPAct) 2005
- Energy Independence and Security Act (EISA) 2007
- American Reinvestment and Recovery Act 2008
- US Farm bill
- Biopreferred Program (procurement of bio-based products)
- New Bioenergy R&D Centres

- National Biofuels Action Plan
- Many State Initiatives (e.g. California Low Carbon Fuel Standard)

A geographical overview of biorefinery projects in the US is given in Figure 2.

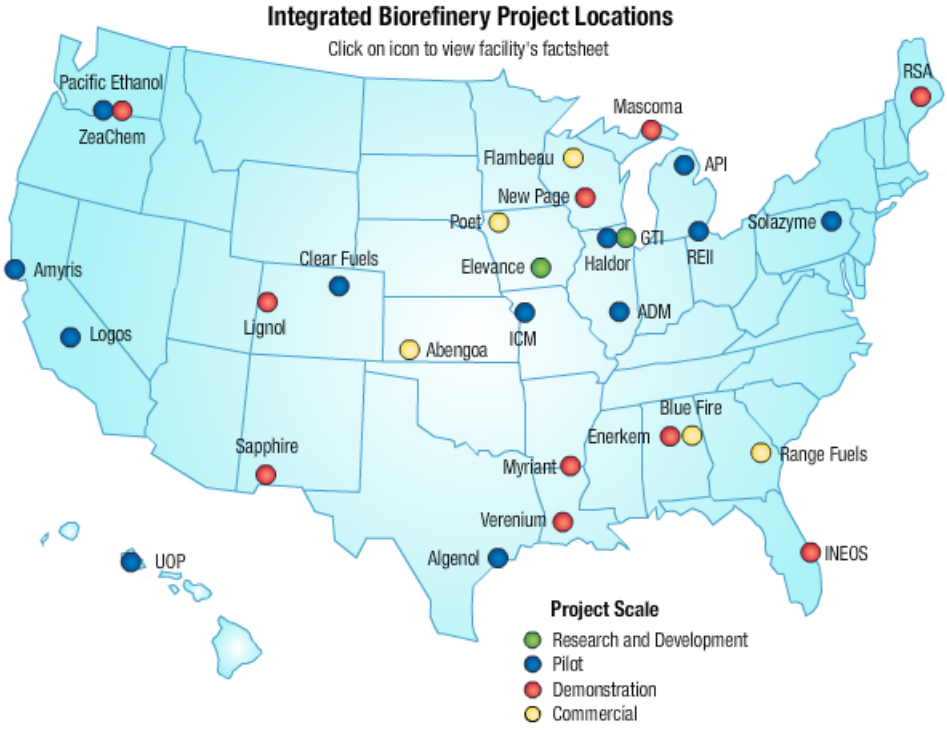

Figure 2 Major DOE biofuel project locations (US-DOE, 2010).

Kamm (2009) gives an overview of the situation in the US (2009). The US is leading in the field of the biobased economy. According to her the main drivers are supply security of raw materials and energy, development of technology and new industries, economical development of the agricultural sector and protection of the environment. In the vision of the US the following aspects should be realized through a combination of R&D and further actions:

- an increase in scientific understanding of the raw material biomass;
- implementation of sustainable systems for development, harvesting and processing of biomass-based raw materials;
- an improvement of conversion efficiency, quality, marketing and technologies for a multitude of products;
- a better market atmosphere and rules, which are necessary for a further development and the employment of biobased fuels, energy and products;
- an improvement of the environment;
- an improved access to the biomass-based raw materials and a participation of the continuation at the development of biomass technologies and their application.

3.2 Funding programmes US

* Name FA **US Department of Energy (DOE) in cooperation with US Department of Agriculture (USDA)**

Name FP Biomass Research and Development Initiative (BRDI)

Main goal The Biomass Research and Development Act established the importance of greater cooperation between Federal agencies in biomass research and development. The Act created The Biomass Research and Development Initiative, which is a solicitation for biomass research issued jointly by the U.S. Department of Agriculture and the U.S. Department of Energy. The Act also established the Biomass R&D Board (Board) and Biomass R&D Technical Advisory Committee (Committee) to help guide the multi-agency effort to coordinate and accelerate all Federal biobased products and bioenergy research and development.
A Comprehensive list of R&D projects and their status that have been awarded under the Biomass Initiative is available for review.

Time status 2002-2006

Budget $US 160 million total in FY2002 – FY2006

Website www.brdisolutions.com

Source BRDI projectlist 2002-2006

* Name FA **US Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE)**

Name FP Biomass Program

Main goal The Biomass Program is helping transform the USA's renewable and abundant biomass resources into cost competitive, high performance biofuels, bioproducts, and biopower.
The Office of Energy Efficiency and Renewable Energy's Biomass Program works with industry, academia, and our national laboratory partners on a balanced portfolio of research in biomass feedstocks and conversion technologies. Through research, development, and demonstration efforts geared toward the development of integrated biorefineries, the Biomass Program is helping transform the nation's renewable and abundant biomass resources into cost competitive, high performance biofuels, bioproducts, and biopower.
The Biomass Program is focusing its research and development (R&D) efforts to ensure that cellulosic ethanol is cost competitive by 2012. Another major effort of the Program is to further develop infrastructure and opportunities for market penetration of biobased fuels and products.
Six companies were selected in February 2007 by the US department of Energy (DOE) to construct demonstration biorefineries that will produce cellulosic ethanol and energy from biomass. The development of three conversion technologies is supported: acid hydrolysis (dilute and concentrated), enzymatic hydrolysis and gasification. The knowledge needed to build these demonstration biorefineries was partly generated in DOE/USDA research projects that were performed in the FY2002 – FY2006 period. The projects will investigate how well these processes will work, and what they will cost. Several lignocellulosic feedstocks will be tested like corn stover, citrus waste, construction waste, wheat straw and wood residues.

- Company - Conversion Technology - Principle Feedstock - Start Up date
- Abengoa - Dilute acid hydrolysis, gasification - corn stover - 2010
- Blue Fire - Concentrated acid hydrolysis - construction waste - 2009
- Poet - enzymatic hydrolysis - corn stover - 2009-2010
- Range Fuels - gasification, catalysis - wood residues - 2011

See an overview of all US-DOE projects in Appendices A & B.

Time status 2007-2017

	Budget	$US 193 million in FY2007 $US 198 million in FY2008 $US 214 million in FY2009 $US 232 million in FY2010 Some of the above budgets for competitive solicitation divided by themes: • Commercial-scale biorefineries (2007) ($US 372M) • Demonstration-scale biorefineries (2008) ($US 275M) • Enzyme cost reduction (2008) ($US 34M) • Ethanologen cost reduction (2007) ($US 23M) • Syngas clean up (2008) ($US 7M) • Universities (2008) ($US 4M) • Pyrolysis (2009) ($US 9M) • Feedstock logistics (2009) ($US 21M) An extra $US 564 million was allocated to 19 projects in December 2009 through the American Recovery and Reinvestment Act in addition to funding for fundamental R&D and ethanol infrastructure compatibility projects.
	Website	http://www1.eere.energy.gov/biomass
	Source	Bioref-Integ (2010)-p5; Biomass program Overview (2010); US-DOE (2009); Koukoulas (2007); Ree & Annevelink (2007)
*	Name FA	**US Department of Agriculture (Washington DC, US)**
	Name FP	Bioenergy Research
	Main goal	The 2007 Farm Bill has major implications for changing farm policy. The Senate Agriculture Committee proposed 15 May 2007 that funding for bioenergy research will use the mechanism of farm support payments. A strategic plan covers research, education and commercialisation. The Rural Development Agency has reviewed feedstocks for the bioeconomy.
	Time status	2007 – 2017
	Budget	$US 500 million over 10 years
	Website	www.usda.gov/wps/portal/usdahome
	Source	St John (2007); USDA Rural Development (2010); USDA ARS (2010)

3.3 Research organisations US

*	Name	**Ames Laboratory (Ames, IA, US);** technology is commercialized by **Catilin Inc. (Ames, IA, US)**
	Main goal	Developed an acid catalyst that can convert animal fat and restaurant oils into a fatty acid free oil, which can be converted into biodiesel by transesterification using conventional biodiesel synthesis. Developed a process to convert glycerol, a by-product of biodiesel production, by using ionic hydrogenation in similar porous structures into 1,3-Propanol.
	Type BR	Oilseed biorefinery
	Time status	
	Budget	
	Website	www.ameslab.gov; www.catilin.com
	Source	Bioref-Integ (2010)-p8&9; Kraus (2006)

*	Name	**Amyris Biotechnologies (Emeryville, CA, US)**
	Main goal	Developed a technology that makes it possible to alter the metabolic pathways of microorganisms such as yeasts, thus creating living factories that produce molecules with practical applications. The modified yeast can make biodiesel from sugar cane, but also from cellulosic biomass.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	Amyris has opened a first pilot plant in September 2008.
	Budget	
	Website	www.amyrisbiotech.com
	Source	Bioref-Integ (2010)-p12

*	Name	**Bio Architecture Lab (BAL, Seattle, WA, US)** and **DuPont**
	Main goal	Examine the potential of macroalgae as feedstock for the production of biobutanol.
	Type BR	Marine Biorefinery
	Time status	
	Budget	$US 9 million grant DOE
	Website	www.ba-lab.com
	Source	Bioref-Integ (2010)-p52

*	Name	**Cargill (Minneapolis, MN, US)**
	Main goal	Developing a building block, 3-hydroxypropionic acid, a platform intermediate that can be produced at a theoretical yield of 100% from glucose.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	www3.dee.nl
	Website	www.cargil.com
	Source	Bioref-Integ (2010)-p17; Cargill biofuels; Cargill industrial products; Millis (2006); Zvozec (2005); Wisbiorefine (2010); Eisberg (2008)

*	Name	**Catilin Inc. (Ames, IA, US)**
	Main goal	Developed a catalytic technique to efficiently extract algal oils without killing the organisms.
	Type BR	Marine Biorefinery
	Time status	
	Budget	
	Website	www.catilin.com
	Source	Bioref-Integ (2010)-p49; Catilin (2009)

*	Name	**Chevron - Strategic research alliances with industry, universities, national laboratories and government** Georgia Institute of Technology, University of California at Davis, U.S. National Renewable Energy Laboratory (NREL), Texas A&M University
	Main goal	Georgia Institute of Technology: to pursue advanced research into viable cellulosic biofuels and hydrogen transportation fuels University of California at Davis: to develop transportation fuels from such renewable resources as rice straw and agricultural waste U.S. National Renewable Energy Laboratory (NREL): to advance the development of renewable transportation fuels Texas A&M University: focusing on the production and conversion of non-food crops into renewable transportation fuels.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.chevron.com
	Source	Bioref-Integ (2010)-p18; Chevron biofuels

*	Name	**Clemson University (Clemson, SC, US)**
	Main goal	Ethanolysis of cottonseed oil into biodiesel high in gossypol content is being studied using potassium hydroxide as catalyst. Research on heterogeneous Mg-Al hydrotalcite base catalysts for the conversion of poultry lipids to biodiesel. Genomics and biotechnological approaches for trait modification of switchgrass - enhancing bioenergy conversion and biomass production.
	Type BR	Oilseed biorefinery; Thermochemical pathway / syngas platform biorefinery
	Time status	
	Budget	
	Website	www.clemson.edu
	Source	Bioref-Integ (2010)-p9; Bioref-Integ (2010)-p41; Luo (2007)

*	Name	**Cornel University – The Angenent Lab (Ithaca, NY, US)**
	Main goal	In the area of bioenergy their goal is to optimize anaerobic fermentation processes to select for undefined mixed cultures that can convert wastes into bioenergy, such as biogas (methane), bioelectricity, and alcohols; and biochemicals, such as butyrate, hydrogen, and hydrogen peroxide. They focus on improving the performance and stability of anaerobic digesters, anaerobic fermenters, and bioelectrochemical systems (including microbial fuel cells [MFCs] and microbial electrolysis cells [MECs]) for waste treatment by optimizing the reactor configuration and/or community selection process. The latter is possible after gaining knowledge on the microbial population dynamics obtained with molecular microbiology techniques based on highly-parallel sequencing (16S rRNA gene surveys and comparative metagenomics) and hybridization methods (DNA arrays). Our work on undefined mixed culture bioprocessing is part of developing and promoting the carboxylate platform in a biorefinery concept. In addition, they are involved in converting lignocellulosic wastes into butanol through two different technologies: 1. a 3-step process, which couples chemical/physical pretreatment with an undefined mixed culture bioreactor and a pure culture solventogenesis bioreactor; and 2. a 2-step process, which couples slow pyrolysis with syngas fermentation. In the research area of bioaerosols, they characterize bacterial pathogens in indoor air with 16S rRNA gene sequencing technologies. Bioelectrochemical systems with living cells are also ideal biosensors. Their lab is performing pure culture studies to optimize the electronic signal and test applications. In addition, we have placed bioelectrochemical systems in Alaskan

		soil to monitor electrochemical activity of the undefined mixed culture.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.cornell.edu; angenent.bee.cornell.edu
	Source	Van Ree & Annevelink (2007); Angenent Lab research
*	Name	**DOE Bioenergy Science Center (BESC), (Oak Ridge, TN, US),** one of the 3 US bioenergy centers. Partners in BESC include Georgia Institute of Technology (Atlanta), NREL, University of Georgia (Athens), University of Tennessee (Knoxville), Dartmouth College (Hanover, NH), ArborGen (Summerville, SC), Verenium Corporation and Mascoma Corporation
	Main goal	Screening of natural thermal springs to identify enzymes and microbes that effectively break down biomass at high temperature as well as trying to understand and engineer cellulosomes (multifunctional enzymes complexes for degrading cellulose). Also, BESC is setting up a 250,000 gallon/a switchgrass to ethanol demonstration plant.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.bioenergycenter.org; www.genomicscience.energy.gov/centers/center_ORNL.shtml
	Source	Bioref-Integ (2010)-p19; BESC partners; BESC interactive map
*	Name	**DOE Great Lakes Bioenergy Research Center (GLBRC), (Madison, WI, US),** one of the 3 US bioenergy centers. The center is led by the University of Wisconsin and Michigan State University and partners are University of Florida (Gainesville), Iowa State University (Ames), Illinois State University (Normal), Lucigen Corporation (Middleton, WI), ORNL and PNNL.
	Main goal	Identification of combinations of enzymes and pretreatments needed to digest specific biomass types.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.bioenergycenter.org; www.greatlakesbioenergy.org
	Source	Bioref-Integ (2010)-p19; GLBRC (2008)
*	Name	**DOE Joint Bioenergy Institute (JBEI), (Berkeley, CA, US),** one of the 3 US bioenergy centers. The center is led by the Lawrence Berkeley National Laboratory (LBNL). Partners include Sandia National Laboratories (SNL, Albuquerque, NM, & Livermore, CA), Lawrence Livermore National Laboratory (LLNL, Livermore, CA), University of California (Berkeley & Davis), Carnegie Institution (CI, Palo Alto, CA)
	Main goal	Developing biotechnologies that can be used for the production of biofuels from biomass. Connecting diverse biological parts and pathways to create entirely new organisms that produce fuels other than ethanol. Engineer organisms to produce and withstand high concentrations of biofuels.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.bioenergycenter.org; jbei.lbl.gov
	Source	Bioref-Integ (2010)-p19; JBEI partners

* Name **Dow Chemical Company (Midland, MI, US), Castor Oil Inc. (Plainview, TX, US) and the USDA Western Regional Research Center (Washington DC, US)**

Main goal Develop technology that can be applied to the production of various chemicals and plastics from seed oils. Development of improved chemicals and plastics from oilseeds.

Type BR Oilseed biorefinery

Time status

Budget

Website www.dow.com; www.castoroilinc.com; www.ars.usda.gov

Source Bioref-Integ (2010)-p10; EERE program achievements; DOW (2010)

* Name **Energy Biosciences Institute (EBI) (Berkely, CA, US + Urbana, IL, US)**

BP has established a 10-year partnership with the University of California at Berkeley and the Lawrence Berkeley National Laboratory to form the Energy Biosciences Institute (EBI). Also, the University of Illinois at Urbana-Campaign (UIUC) has established a partnership with EBI. BP also collaborates with Princeton University

Main goal Research on cellulosic ethanol from non food and food feedstocks, initially focussing on grasses, energy cane (a variety of sugar cane with higher crop yields), and sugar cane. Range of projects:

- Examination of ionic liquids (ILs) and ionic liquid/co-solvents with tunable properties for their ability to dissolve the cellulosic components of lignocellulosic biomass.
- Study of structure-function relation of cellulosomes for the degradation of lignocellulose into biofuels
- The potential of thermophilic microorganisms to hydrolyze cellulose and hemicellulose, as well as ferment glucose, and in some instances xylose, to ethanol.

Type BR Lignocellulosic feedstock biorefinery

Time status

Budget $US 500 million

Website www.energybiosciencesinstitute.org

Source Bioref-Integ (2010)-p16&23; Eyton (2008)

* Name **Idaho National Laboratory (INL) (Idaho Falls, ID, US)**

Main goal Idaho National Laboratory's (INL's) Bioenergy Program funded by the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy's Biomass Program, embraces the "Whole Crop Utilization" concept (using the entire crop, including the grain and traditionally discarded plant biomass) to produce food, feed, fiber, and energy.

The goal of INL's program is to overcome key technical barriers facing the U.S. bioenergy industry by systematically researching, characterizing, modeling, demonstrating, and harnessing the physical and chemical characteristics of the nation's diverse agricultural residues to more cost-effectively produce biofuels and other value-added products.

Research includes:

- identify sufficient, sustainable agricultural residue supplies;
- document and update feedstock resource data for all significant agricultural residue resources and provide access to the national feedstock database via the Internet;
- develop technologies and methods to harvest and collect sufficient quantities of agricultural residues on an annual basis;
- develop and demonstrate innovative feedstock storage methods;

- demonstrate feedstock transportation cost reductions;
- demonstrate preprocessing technologies that produce agricultural residue resources with bulk, flowable properties;
- develop and validate optimum process and cost models for sustainable feedstock supply systems;
- show that agricultural residue feedstocks could be supplied to biorefineries within target cost ranges.

Type BR Whole crop biorefinery
Time status
Budget
Website www.inl.gov
Source INL Research

* Name **Iowa State University (Ames, IA, US)**
Main goal Research on soybean oil based resins and composites.
Possibilities to convert lignin from the pyrolytic bio-oil process into valuable products.
Type BR Oilseed biorefinery; Lignocellulosic Feedstock Biorefinery issues: Lignin platform
Time status
Budget
Website www.iastate.edu
Source Bioref-Integ (2010)-p10&48; Larock (2009); Aurand (2007)

* Name **Iowa State University (Ames, IA, US) – Bioeconomy Institute (BEI)**
Main goal The Bioeconomy Institute (BEI) at Iowa State University seeks to advance the use of biorenewable resources for the production of chemicals, fuels, materials and energy. The Bioeconomy Institute was established to provide cohesion among the diverse efforts in biorenewable resources on campus and to encourage collaboration within departments, colleges and research units. Currently, the Bioeconomy Institute engages all 7 colleges, 29 departments, and partners with 27 research centers and institutes.
BEI is working on the following Soybean Biorefinery Programs:

- development of Soybean-Based Biorenewable Source of Fuels and Lubricants;
- diols from polyols;
- advanced biorefinery feedstocks;
- chemical methodologies and library development;
- development of soy/corn oil plastic composites;
- conjugation of soybean oil for use as ink and alkyd resin-drying oils;
- barium oxide as an heterogeneous recyclable catalyst for conversion of oils and fats to biodiesel;
- enzyme-assisted aqueous processing of soybeans;
- global soybean meal quality update;
- The 2004 Soybean Quality Report of the United States Soybean Crop.

Type BR Oilseed biorefinery
Time status 2002 - now
Budget Over $US 51 million in cumulative sponsored research funding from industry and federal agencies ranging from the Department of Agriculture to the National Science Foundation.
Website www.biorenew.iastate.edu
Source BEI research; BEI soybean biorefinery

* Name **Iowa State University (Ames, IA, US) - Center for Sustainable Environmental Technologies (CSET)**

Main goal A syngas fermentation program that explores hybrid thermochemical/ biological processing of biomass. The gaseous mixture resulting from the gasification of carbonaceous feedstocks can be fermented to various products including carboxylic acids, alcohols, esters, and hydrogen.

- Together with Iowa Energy Center, Iowa State University has developed a thermally ballasted gasifier that uses a single reactor for both combustion and pyrolysis of switchgrass into hydrogen-rich gas.
- In partnership with ConocoPhillips Company, will test an integrated biomass-to-liquids system that uses gas cooling through oil scrubbing rather than water scrubbing in order to minimize waste water treatment. Switchgrass will be the biomass feedstock fed into the gasifier. The gas-oil scrubbing liquid will then be sent to a coker in existing petroleum refining operations to be used as a feedstock.
- Developing an integrated system of thermochemical and catalytic technologies to efficiently produce ethanol from plant biomass.
- Research on enzymatically modified soy protein adhesives
- Treating fuel ethanol with ozone and activated carbon can economically remove impurities so the alcohol can be used by the beverage industry.

Type BR Thermochemical pathway / syngas platform biorefinery
Time status
Budget
Website www.cset.iastate.edu
Source Bioref-Integ (2010)-p44&45; CSET research projects

* Name **Iowa State University (Ames, IA, US) – Iowa Energy Center**

Main goal Advancing Iowa's energy efficiency and renewable energy use through research, education and demonstration. Bridging the gaps between laboratory research and real world applications is a hallmark of the Iowa Energy Center. In this tradition, the Energy Center created the Biomass Energy CONversion facility (BECON), located in Nevada, Iowa. BECON is a focal point for developing value-added products from Iowa's abundant biomass resources. It provides credible, firsthand information on biomass technologies to create fuels and chemicals, as well as demonstrations of pilot-scale biomass conversion systems.

Type BR Lignocellulosic feedstock biorefinery
Time status
Budget
Website www.energy.iastate.edu
Source BECON (2010);

* Name **Kansas State University (Manhattan, KS, US)**

Main goal Catalytic deoxygenation of fatty acids into alkanes and alkenes, using ZnO, alumina and zeolite ZSM-5.

Type BR Thermochemical pathway / syngas platform biorefinery
Time status
Budget
Website www.k-state.edu
Source Bioref-Integ (2010)-p46; More (2006)

*	Name	**Lawrence Berkely National Laboratory (LBNL) (Berkely, CA, US)**
	Main goal	Leads the DOE Joint Bioenergy Institute (JBEI).
	Type BR	
	Time status	
	Budget	
	Website	www.lbl.gov
	Source	

*	Name	**Los Alamos National Laboratory (LANL) (Los Alamos, New Mexico, US)**
	Main goal	Los Alamos National Laboratory will play a key role in helping develop advanced biofuels for transportation, thanks to funding from the American Reinvestment and Recovery Act (ARRA). Under the two ARRA proposals, two separate consortia will develop "green" fuels such as gasoline, diesel, or jet fuel from algae and other renewable feedstocks. The first ARRA project will develop and demonstrate the science and technology necessary to significantly increase production of algal biomass and lipids, efficiently harvest and extract algae and algal products, and establish valuable certified coproducts that scale with renewable fuel production. Coproducts include animal feed, industrial feedstocks, and additional energy generation. Multiple test sites will cover diverse environmental regions to facilitate broad deployment. The second ARRA project belongs to the National Advanced Biofuels Consortium (NABC) and will be led by the National Renewable Energy Laboratory (NREL) and Pacific Northwest National Laboratory (PNNL). The NABC initiative will conduct cutting-edge research to develop infrastructure compatible, biomass-based hydrocarbon fuels. The result will be a sustainable, cost-effective production process that maximizes the use of existing refining and distribution infrastructure. NABC will investigate a variety of process strategies and select those closest to larger-scale demonstration. The NABC plans to further develop these strategies to deliver a pilot-ready process, with full lifecycle analysis to measure the environmental benefits.
	Type BR	Marine biorefinery; Lignocellulosic feedstock biorefinery
	Time status	
	Budget	first ARRA project awarded $US 44 million second ARRA project awarded $US 34 million
	Website	www.lanl.gov
	Source	LANL biofuels

*	Name	**Mascoma Corporation (Lebanon, NH, US)**
	Main goal	Developing innovative and cost effective advances in biotechnology and engineering to unlock the potential of biomass for the production of ethanol. In particular, the company develops the Consolidated Bio-Processing (CBP) technology, which follows a mild pretreatment and avoids the need for the costly production of cellulase enzymes by using engineered microorganisms that produce cellulases to hydrolyze the cellulose and ferments sugars into ethanol at high yield in a single step.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.mascoma.com
	Source	Bioref-Integ (2010)-p26

* Name **Metabolix Inc. (Cambridge, MA, US)**
Main goal Developing proprietary technology platforms for the co-production of biobased plastics, chemicals, and energy in non-food crops, such as switchgrass.
Type BR Lignocellulosic feedstock biorefinery
Time status
Budget
Website www.metabolix.com
Source Bioref-Integ (2010)-p27; Metabolix (2008)

* Name **Michigan State University (East Lansing, MI, US) – Office of Biobased Technologies**
Main goal The Michigan State University Office of Biobased Technologies (OBT) aims to integrate innovations in the lab with advances in the marketplace. MSU strengths are:

- Plant scientists who understand how plants produce biomass at the most fundamental metabolic levels and who have expertise in using molecular and genetic tools to improve these processes.
- A comprehensive knowledge base in all facets of agricultural science. Researchers and educators are tightly linked to the state's agricultural, natural resources and forestry industries and are skilled in applying scientific advances to the real world.
- Expertise in biological and chemical processing of plant material.
- Experts in complex supply chain management, which will be critical to move from raw plant materials to finished bioproducts.

Type BR
Time status 2006 - now
Budget
Website www.msu.edu; bioeconomy.msu.edu
Source Van Ree & Annevelink (2007)

* Name **Mississippi State University (Swalm, MS, US)**
Main goal Research on oleaginous yeast *Rhodotorula glutinis*, which has the ability to produce up to 70% of its weight as oil in the form of triacylglycerol (TAG), which can be a feedstock for biodiesel production. Feedstock for the yeast can be glucose and glycerol, a key by-product of same biodiesel production.
Type BR Lignocellulosic feedstock biorefinery
Time status
Budget
Website www.msstate.edu
Source Bioref-Integ (2010)-p28

* Name **Montana State University (Bozeman, MT, US) with Utah State University (Logan, UT, US)**
Main goal Evaluate the oil content of algae cultures and identify populations that naturally have higher rates of oil production.
Test the oil producing microalgae in existing open ponds for growth characteristics and oil production and determine the optimal algae type and most efficient biorefinery design.
Type BR Marine Biorefinery
Time status
Budget
Website www.montana.edu; www.usu.edu
Source Bioref-Integ (2010)-p51; US DOE (2008)

* Name **National Renewable Energy Laboratory (NREL) (Golden, CO, US).**
One of the key partners in the US DOE Biomass Program and leads the DOE National Bioenergy Center.

Main goal Through biomass research, NREL is developing technologies to convert biomass - plant matter such as trees, grasses, agricultural residue, algae, and other biological material - to fuels. These biofuels will reduce our nation's dependence on foreign oil, improve our air quality, and support rural economies. Biomass capabilities and projects at NREL are focused on:

- biomass characterization;
- biochemical conversion;
- thermochemical conversion;
- chemical and catalyst science;
- integrated biorefinery processes;
- microalgal biofuels;
- biomass process and sustainability analyses.

NREL is the lead national laboratory of the virtual National Bioenergy Center, which supports and coordinates the nation's biomass research activities. NREL research activities are:

- Developing, integrating, and demonstrating biochemical and thermochemical conversion technologies, and renewable diesel technologies. Focus within NREL's biochemical conversion technologies is on pretreatment, cellulose enzymes, catalysts for products from sugars, sugar platform integration and corn ethanol production improvement.
- Also developing thermochemical conversion routes, because the lignin-rich parts –constituting about one third of biomass weight– cannot be easily converted biochemically. Focus is on syngas production and utilization, gasifier system development, and rural energy systems.
- Research on algae cultivation and harvesting, and oil production.

Type BR Lignocellulosic feedstock biorefinery; Thermochemical pathway / syngas platform biorefinery; Marine Biorefinery

Time status

Budget

Website www.nrel.gov/biomass

Source Bioref-Integ (2010)-p28&46& 50; NREL report cellulosic ethanol (2007); NREL projects; NREL (1998); NREL capabilities; NREL biorefinery

* Name **Oak Ridge National Laboratory (ORNL) (Oak Ridge,TN,US)**
One of the key partners in the US DOE Biomass Program. Managed by a partnership of the University of Tennessee and Battelle.

Main goal Oak Ridge National Laboratory is the Department of Energy's largest science and energy laboratory.
ORNL is one of the world's premier centers for R&D on energy production, distribution, and use and on the effects of energy technologies and decisions on society. Clean, efficient, safe production and use of energy have long been our goals in research and development. At ORNL, unique facilities for energy-related R&D are used both for technology development and for fundamental investigations in the basic energy sciences that underpin the technology work.
Oak Ridge National Laboratory's bioenergy R&D supports DOE's Office of Energy Efficiency and Renewable Energy's Biomass Program, as well as DOE's , working with industry, academia and national labs on a balanced portfolio of research in biomass feedstocks and conversion technologies. Through research, development and demonstration efforts geared toward the development of integrated biorefineries, it is helping transform the nation's renewable and

		abundant biomass resources into cost competitive, high performance biofuels, bioproducts, and biopower. ORNL biorefinery-relevant research ranges from basic genetic research to understand the genetic controls on enzymes that break cellulose into its component sugars – the first step to creating ethanol, to research on how to transform lignin into carbon fibers that could replace the steel in cars, to understanding how materials respond to the chemical and temperature conditions in biomass gasifiers.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	2000 – now
	Budget	
	Website	www.ornl.gov
	Source	Bioref-Integ (2010)-p28; Bioenergy Feedstock Information Network (BFIN); ORNL energy; ORNL bioenergy programme; ORNL biorefinery research
*	Name	**Pacific Northwest National Laboratory (PNNL) (Richland, WA, US)**
	Main goal	The specific objective of the DOE funded project 'Value-Added Products from Hemicellulose Utilization in Dry-Mill Ethanol Plants' is to create value-added products from ethanol dry-mill facilities. The project will integrate highly efficient fermentations with high-yielding aqueous-phase catalysis to create substantial value. The objective of the project 'Corn Fiber Processing' was to develop an economic process for the separation of corn fiber into its core building blocks. This project is developing a technology platform to separate these component groups and convert them into the core building blocks; glucose, arabinose, xylose, ferulic acid, and the specific components of the oil fraction: triglycerides, and sterols. The most abundant core building blocks, glucose, xylose and arabinose are being evaluated as a feedstock for either fermentation to ethanol or direct aqueous phase catalytic conversion to proylene glycol, ethylene glycol, and glycerol. The ferulic acid will be evaluated as a feedstock for the production of vanillin. The 'Isosorbide Production' project focuses on developing new catalytic materials and novel processes for the conversion of sorbitol to isosorbide. Isosorbide (1,4-3,6-dianhydrosorbitol) is derived from the acid catalyzed cyclic dehydration of sorbitol, which in turn is derived from glucose via hydrogenation. The object of this project is two-fold: (1) develop an improved process that increases the yield to isosorbide and (2) create a more environmentally benign process. The project 'Catalytic Gasification of Wet Biomass' provides the process development of a catalytic gasification technology for recovery of energy from wet biomass including biosludge and unconverted residuals from ethanol fermentation. The work includes preliminary batch reactor testing with the wet biomass materials; bench-scale continuous-flow process testing to develop process kinetics and address various handling issues, including removal of sulfur and minerals; scale-up testing in a half-ton per day processing unit to verify scale-up of the process; and a conceptual plant design and costing effort to provide a basis for commercial application of the technology. Techno-economic feasibility of offshore seaweed farming for bioenergy and biobased products. Finally PNNL has a project called 'Upgrading Of Biomass Fast Pyrolysis Oils To Higher Value Liquid Fuels'. For this bio-oil (fast pyrolysis of biomass) upgrading process development, research will be conducted in existing bench-scale batch reactor systems at PNNL to evaluate new catalysts and a bench-scale continuous flow reactor operated with bio-oil feedstocks and feedstock fractions to determine kinetic parameters for the conversion and catalyst deactivation and lifetime data. The process test results will be used to provide a new basis for process economics.
	Type BR	Lignocellulosic feedstock biorefinery; Marine Biorefinery
	Time status	

	Budget	
	Website	www.pnl.gov
	Source	Bioref-Integ (2010)-p52; PNNL report 18944 catalytic hydrothermal gasification of lignin-rich biorefinery residues and algae; PNNL project gasification; PNNL projects

*	Name	**Purdue University (West Lafayette, IN, US)**
	Main goal	Research is taking place throughout multiple departments within the College of Agriculture at Purdue University to evaluate the integration of co-products from corn ethanol production into livestock feeding. The stages within the full cycle of utilizing these co-products includes: • processing, storage, and handling; • nutrient digestibility; • animal performance; • carcass quality; • economic value as a feed ingredient; • impacts of ethanol co-products on manure composition and nutrient management; • economic assessment of diets using co-products; and • ethanol plant proximity near livestock production affects on supply and demand.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.extension.purdue.edu/renewable-energy/index.shtml
	Source	Bioref-Integ (2010)-p29; Mosier (2007); Purdue bioenergy; Purdue biofuels byproducts

*	Name	**Purdue University (West Lafayette, IN, US) – Laboratory of Renewable Resources Engineering (LORRE)**
	Main goal	The Laboratory of Renewable Resources Engineering, LORRE, was established to carry out research on transforming renewable resources to liquid fuels. The role of the Laboratory in multidisciplinary research evolved over its 31-year history from biofuels research to its current function as an Integrative Center for Biotechnology and Engineering which carries out multi-disciplinary research in bioenergy, bioprocessing bioproducts , bionanotechnology, and biorecovery. LORRE has capabilities ranging from fundamental studies on the molecular genetics of yeast and bacteria to bioreaction and bioprocess engineering, and biotechnology that uses organisms, tissues, cells, or their molecular components to: • act on living things, • intervene in the workings of cells, including their genetic material, • provide templates for advanced non-living systems that emulate specific biological functions, and • manufacture bioproducts.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	1978 - now
	Budget	
	Website	http://cobweb.ecn.purdue.edu/~lorre/16/overview/index.shtml
	Source	Bioref-Integ (2010)-p29;

* Name **South Dakota State University (Brookings, SD, US)**

Main goal Evaluate the use of ultrasound, microwave, and 'clean fractionation' pretreatment techniques for lignocellulosic ethanol production.
South Dakota State University researchers have developed a four year research program 'Prairie Biorefinery' to assess the potential of prairie cord grass (PCG) to serve as high yielding, perennial biomass crop, and to develop conversion technologies to process PCG and other sources of biomass into useful products.
Three subprojects were defined:

- genetic diversity of prairie cord grass in relation to its potential as biomass crop;
- pretreatment strategies for biochemical conversion of prairie cord grass;
- thermo-economic and environomic analysis of the thermochemical processing of prairie cord grass.

Type BR Lignocellulosic feedstock biorefinery
Time status 2008-2011
Budget
Website www.sdstate.edu
Source Bioref-Integ (2010)-p57; Julson (2008); SDS developing prairie biorefinery

* Name **Texas A&M University (College Station, TX, US)**

Main goal Developed the MixAlco process a method for producing fuels from biomass, such as municipal waste, agricultural residues, sewage sludge, and manure. The biomass is treated with lime and air to enhance digestibility. This material is fed to a mixture-culture of microorganisms that produce carboxylic acids, which are transformed into salts by addition of $CaCO_3$. After drying, the salts are thermally converted into ketones. Finally, the ketones are hydrogenated to alcohols.
Type BR Lignocellulosic feedstock biorefinery
Time status
Budget
Website www.tamu.edu
Source Bioref-Integ (2010)-p33; Holtzapple (2005)

* Name **University of Georgia (Athens, GA, US) –**
The faculty of engineering

Main goal

- Developing integrated systems for the conversion of biomass to chemicals, fuels, and bio-products. The evaluated technologies include: pre-treatment of biomass for fermentation, anaerobic digestion, bioethanol and biodiesel production.
- Developing integrated systems for the conversion of biomass to chemicals, fuels, and bio-products.
- The evaluated technologies include: pyrolysis, in particular its kinetics, gasification, carbon sequestering fertilizer (ECOSS), and direct or co-firing with coal.
- Develop novel approaches to supply nutrients to oil-producing algal systems resulting in cost-effective algae-biofuel production systems.
- Develop process methods for the harvesting of algae from open ponds and subsequent processing to biofuels and other value added products from algae.

Type BR Lignocellulosic feedstock biorefinery; Thermochemical pathway / syngas platform biorefinery; Marine Biorefinery
Time status
Budget
Website www.engr.uga.edu
Source Bioref-Integ (2010)-p34&47&51; Das (2005); US DOE (2008)

* Name **University of Iowa (Iowa City, IA, US)**
Main goal Transformation of biomass into sugars and other compounds using subcritical and supercritical water conditions.
Type BR Thermochemical pathway / syngas platform biorefinery
Time status
Budget
Website www.uiowa.edu
Source Bioref-Integ (2010)-48; Aurand (2007)

* Name **University of Minnesota (St. Paul, MN, US) – The BioTechnology Institute**
Main goal The BioTechnology Institute is the central University of Minnesota vehicle for coordinated research in the biological, chemical, and engineering aspects of biotechnology. The University of Minnesota has a long tradition and world-class expertise in the science of biocatalysis, the use of biological catalysts and processes to transform plant material into useful products.
The University of Minnesota Biocatalysis Initiative was created to focus and fund research in the areas of industrial biocatalysis and chemical biotechnology - biological processes which promise a safer and more sustainable future.
A critical element of the Interdisciplinary Initiative on Biocatalysis is the development of a strong interdisciplinary research program in biocatalysis that will build new research clusters in two areas: Industrial Biocatalysis and Chemical Biotechnology. Both of these areas rest on a common platform of chemical and biochemical science, genetics, chemical engineering (including microbial and bio-based products engineering), genomics, proteomics, and bioinformatics.
Type BR
Time status
Budget
Website www.bti.umn.edu
Source Van Ree & Annevelink (2007); BTI biocatalysis initiative

* Name **University of Missouri (Columbia, MO, US) - The National Center for Soybean Biotechnology (NCSB)**
Main goal The U.S. Congress selected the University of Missouri to host the National Center for Soybean Biotechnology (NCSB) based on our record of interdisciplinary research on soybean genetics, genomic, and related sciences. The ultimate goal of the NCSB is to provide innovative molecular approaches that can be applied toward soybean improvement. It's mission is to:

- Provide genomic resources and bioengineering technologies to support the U.S. soybean industry.
- Improve the profitability of soybean production for U.S. producers by enhancing yield, pest and pathogen resistance, abiotic stress tolerance and value-added traits.
- Provide educational opportunities in soybean biotechnology at the primary education, undergraduate, and graduate level.
- Conduct outreach and extension activities to inform the producers and the general public about the latest scientific discoveries and developments in soybean biotechnology and products.

Type BR Oilseed biorefinery
Time status
Budget
Website www.missouri.edu; www.soybiotechcenter.org
Source Van Ree & Annevelink (2007)

*	Name	**University of Tennessee (Knoxville, TN, US) - Office of Bioenergy Programs**
	Main goal	The Office of Bioenergy Programs at the University of Tennessee is actively working toward a secure and sustainable energy future for the state and nation. Housed in the Institute of Agriculture, the Office of Bioenergy Programs coordinates a variety of research, development, and outreach programs, all involving bioenergy. The Institute of Agriculture has research programs in biomass feedstock development and production, biomass pretreatment and processing, biomass conversion technologies, and biobased products, such as fuels, polymers, and chemicals. The Tennessee Biofuels Initiative, an innovative research and business model that will position the state as a leader in the nation's efforts toward commercially viable biofuels production, the UT Institute of Agriculture is among the nation's top tier academic institutions working on solutions for the nation's energy needs. The Initiative is partnering the research capabilities of UT, Oak Ridge National Laboratory and private industrial partners with farmers and landowners in Tennessee with the goal of producing cellulosic ethanol as a transportation fuel.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.utk.edu; www.utbioenergy.org
	Source	Van Ree & Annevelink (2007); UT bioenergy educational program Biosucceed; UT bioenergy research

*	Name FA	**University of Wisconsin (Madison, WI, US) – Wisconsin Biorefining Development Initiative™** Project funding sponsors are the US DOE – Chicago Regional Office, and the State of Wisconsin Department of Administration – Division of Energy. Contributions from a wide range of organizations and programs, including: Energy Center of Wisconsin, University of Wisconsin-Madison, CleanTech Partners Inc. (formerly Center for Technology Transfer), Oak Ridge National Laboratory, National Renewable Energy Laboratory, Pacific Northwest National Laboratory, USDA, Forest Products Laboratory & DOE Biomass Program.
	Main goal	Help Wisconsin expanding biorefining activities by introducing new opportunities for refining multiple, higher-value products from biomass materials and waste streams. Research topics are e.g.: • Integrated Catalytic Conversion of γ-Valerolactone to Liquid Alkenes for Transportation Fuels. • Using algae, brine shrimp and tilapia, researchers have designed a novel system that extracts oil for use as biofuel.
	Type BR	Lignocellulosic feedstock biorefinery; Marine biorefinery
	Time status	2007 - now
	Budget	
	Website	www.wisc.edu; www.wbi.wisc.edu
	Source	Bioref-Integ (2010)-p36;

*	Name	**Virginia Polytechnic Institute and State University (Blacksburg, VA, US) – Institute for Critical Technology and Applied Science (ICTAS)**
	Main goal	ICTAS is actively researching the development and utilization of renewable biomass resources for new materials and fuels in order to create the basis of a sustainable global industry. Fundamental research is investigating the key molecular features associated with the structure and function of materials that are being intelligently designed to replace petroleum-based polymers. The Bio-Based Materials Design and Processing Group of ICTAS has the following research areas: • biofuel feedstock from microalgae, biogas production from animal waste, and developing high-value nutraceuticals from biodiesel waste stream; • chemical and fuel production through pyrolysis of biomass; • efficient sugar liberation from biomass and biofuels production; • polysaccharide derivatives for enhanced drug delivery; • polysaccharide nanocrystals for biomedical applications and materials; • layer-by-layer assembly of polysaccharides; • biopolymer surface characteristics; • bioprocessing and biomaterials; • Life Cycle Assessment of bio-based materials and processes.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.vt.edu; www.ictas.vt.edu
	Source	Bioref-Integ (2010)-p36; ICTAS renewable materials; ICTAS Bio-Based Materials Design and Processing Group

*	Name	**Qteros (Marlborough, MA, US),** (formerly SunEthanol), a spin off from the University of Massachusetts
	Main goal	Optimizing a naturally occurring microbe, which the company calls the Q Microbe, to make ethanol.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.qteros.com
	Source	Bioref-Integ (2010)-p36

*	Name	**ZeaChem (Lakewood, CO, US)**
	Main goal	Biorefinery cellulosic ethanol technology using a hybrid combination of biochemical and thermochemical processing steps
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.zeachem.com
	Source	Bioref-Integ (2010)-p37; Zeachem (2010); LaMonica (2009)

3.4 Pilot plants US

Recently awarded pilot scale projects in the US are described in Annex B.

4 Canada

4.1 Introduction Canada

In Canada biorefinery research has to compete for R&D funds with clean fossil fuels, carbon sequestration and next generation nuclear programs (Wellisch, 2009).

No national bioenergy target, only a modest biofuel target and no bioproduct procurement programs exist in Canada (Wellisch, 2009). Some provincial bioproduct procurement programs are being developed.

The main driver for biorefineries in Canada are finding new sustainable economic opportunities for forestry and agriculture industries and secondly rural economic development (Wellisch, 2009). The approach is provincial action with national coordination. Canadian policy has set a Renewable Fuels Standard for biofuels and is giving support for biofuel plant construction and R&D funding. Many projects are still in the pilot or R&D stage (not yet commercial). Mainly new technologies are being developed for typical Canadian lignocellulosic feedstocks (forest and agriculture). Also new industrial crops are being developed. Environmental implications are taken well into account.

Figure 3 Map of Canada (source: www.mapsofworld.com/canada/canada-political-map.html).

Canada is currently very active in the area of biorefinery development (Wellisch, 2009). On the short term development appears to be very biofuels/bioenergy focused (vs chemicals and materials). Besides technology development also a more systems (engineering) approach is needed, together with sustainability assessments.

There has been much interest in Canada in the concept of the forest biorefinery from the research community, the forest industry, and policy makers (Towers et al., 2007). Three critical factors that need to be examined are feedstocks, conversion and separation technologies, and markets for products. The nature of the Canadian feedstocks and the value of the products will drive technical development of the biorefineries.

A list of proposed research activities mainly on the LCFBR type of biorefinery in connection with the traditional pulp & paper industry is given in Table 1.

Table 1 Proposed research activities in Canada (Towers, et al., 2007).

Title	Description
Product opportunity analysis	Market analysis; high value vs high volume products
Availability of forest feedstocks	Available biomass (forest, sawmill, pulp mill, agricultural or other residues): costs, logistics, etc.
Thermochemical pathways	Gasification and pyrolysis pathways to novel products
Bioproducts from effluent and solid wastes	Bio-degradable plastics; products from anaerobic treatment systems; value-added uses of sludges
Products from hemicellulose	Extract fuels and specialty chemicals while maintaining pulp properties
Products from lignin	Extraction of lignin from Kraft black liquor, and its use in novel products
Products from extractives	Synthetic diesel and other products from crude tall oil
Products from condensates	Methanol extraction, purification, and transformation processes
Phytochemicals	Novel high value, low volume products from bark, branches and foliage
Integrating novel products with existing product lines	Maintaining pulp and paper properties while modifying existing mills for novel products
Conversion of uncompetitive mills	Identifying new uses for idled Kraft production lines, in particular batch pulping systems
Integration with other industries	Identify synergies with commercial, industrial or domestic neighbours

4.2 Funding programmes Canada

*	Name FA	**Agriculture & Agri-Food Canada (AAFC) (Ottawa, ON, Canada)**
	Name FP	Agricultural Bioproducts Innovation Program (ABIP)
	Main goal	The Agricultural Bioproducts Innovation Program (ABIP) is a multi-year program that seeks to mobilize Canada's creative talent in academia and in the private and public sectors and to integrate resources to build greater research capacity in agricultural bioproducts and bioprocesses. Through supporting networks and clusters, the program promotes research, development, technology transfer and commercialization activities in areas such as biofuels, other forms of bioenergy, industrial chemicals, biomaterials, and health products. Through its nine Networks, ABIP involves 36 Universities, 52 Industry Groups and 19 Governments: • Cellulosic Biofuels Network (CBN) • Sustainable Cropping System Platforms for Biodiesel Feedstock Quantity and Quality (SBQQ) • Agricultural Biorefinery Innovation Network for Green Energy, Fuels & Chemicals (ABIN) • Canadian Triticale Biorefinery Initiative (CTBI) • Feed Opportunities from the Biofuels Industries (FOBI) • Industrial Oil Seed Network (IOSN) • Natural Fibres for the Green Economy Network (NAFGEN) • Pulse Research Network (PURENet) • BioPotato Network: a Canadian network for potato-based bioproducts (BioPotato)
	Time status	2008-2011
	Budget	Total $145 M
	Website	www.agr.gc.ca/abip
	Source	Wellisch (2009 & 2010)

*	Name FA	**Agriculture & Agri-Food Canada (AAFC) (Ottawa, ON, Canada)**
	Name FP	Canadian Agricultural Adaptation Program (CAAP)
	Main goal	The Canadian Agricultural Adaptation Program (CAAP) is a successor to the Advancing Canadian Agriculture and Agri-Food (ACAAF) program. It has the objective of facilitating the agriculture, agri-food, and agri-based products sector's ability to seize opportunities, to respond to new and emerging issues, and to pathfind and pilot solutions to new and ongoing issues in order to help it adapt and remain competitive. The CAAP intends on funding projects identified by the sector that align with priorities identified by industry and/or government at the national, regional, and multi-regional levels by focusing on: • Seizing opportunities • Responding to new and emerging issues • Pathfinding and piloting solutions to new and ongoing issues
	Time status	2009-2014
	Budget	$163 M
	Website	
	Source	CAAP (2010)

*	Name	**Alberta Agricultural Research Institute (AARI) (Edmonton, AL, Canada)**
	Name FP	
	Main goal	The Alberta Agricultural Research Institute (AARI) is the primary agency in Alberta for funding, coordinating and promoting strategic agricultural initiatives in research, development and technology transfer for the agriculture and agri-food sector. AARI's main strategic areas of funding include: • functional foods and nutraceuticals; • crop/livestock genomics; • bio-energy; • greenhouse gases (reductions/offsets); • bio-fibres and bio-polymers; • value-added products (crops and livestock).
	Time status	2006-2008
	Budget	
	Website	www.aari.ab.ca/index2.cfm
	Source	Canadabusiness; AARI project database; AARI approved projects 2006-2008

*	Name FA	**Genome Canada (Ottawa, ON, Canada)**
	Name FP	Applied Genomics Research in Bioproducts or Crops
	Main goal	Supports applied genomics research in two themes: • bioproducts, and • crops. The Bioproducts Theme Research projects have to employ genomic and proteomic approaches to understand and manipulate the underlying biological processes exploited in the production of economically viable and environmentally sustainable bioproducts. The following 3 areas were targeted: • feedstock optimization; • microorganisms for sustainable processing technologies, and; • value added-bioproducts. See website for project list.
	Time status	multiyear (starting in 2009)
	Budget	$112 M in 12 projects
	Website	www.genomecanada.ca/en
	Source	Genomecanada projects (2010)

*	Name FA	**Government of Alberta (Edmonton, AL, Canada)**
	Name FP	Biorefining Commercialization and Market Development Program (BCMDP) Alberta
	Main goal	• Biorefining Development - To assist the expansion or new development of biorefining in Alberta. • Technology Development and Commercialization - To assist biorefiners to analyze opportunities and evaluate and adopt new technologies. • Market Development - To assist biorefiners to meet market requirements, penetrate new markets and pursue import replacement opportunities.
	Time status	2007 - 2011
	Budget	Total of $239 M from Alberta's Nine-Point Bioenergy Plan; February 2007 – March 2009: $ unknown M
	Website	
	Source	Philips (2007a); Alberta (2010a); Alberta (2010b) ; Alberta (2010c); Wellisch (2010)

*	Name FA	**National Research Council of Canada (NRC) (Ottawa, Ontario, Canada)**
	Name FP	National Bioproducts Program (NBP)
	Main goal	Its objective is to catalyze collaboration between NRC, industry, government departments, university, and other research organizations to develop commercializable technologies over the next three to five years which will have a net positive impact on our environment, sustainable energy and rural revitalization. It has bioindustrial projects in progress at several of its Research Institutes, such as Plant Biotechnology Institute, Innovative Materials Institute, and Biotechnology Research Institute.
	Time status	3 years
	Budget	Reallocation of internal funds
	Website	www.nrc-cnrc.gc.ca/eng/ibp/nbp.html
	Source	Wellisch (2009 & 2010); Phillips (2007b)

*	Name FA	**National Research Council of Canada (NRC) (Ottawa, Ontario, Canada)**
	Name FP	R&D initiative on bioproducts for application in construction
	Main goal	Development of new biomaterials, and the investigation of their performance and long-term durability including, for instance, applications in water protection, biofibre-reinforced materials, insulation, and thermal storage.
	Time status	
	Budget	
	Website	www.nrc-cnrc.gc.ca/eng/ibp/irc/ci/v14no2/7.html
	Source	Wellisch (2010)

*	Name FA	**Natural Resources Canada (NRCan) (Ottawa, Ontario, Canada)**
	Name FP	Biomass for Energy Program
	Main goal	The CFS program attempts to: identify sources of increased biomass supply, for both existing and 'new' biomass; develop efficient methods of growing, harvesting, collection and transportation; and demonstrate the sustainability of increased biomass supply. Research areas are: forest biomass; feedstock supply; assessment of biomass resources in the fields of forestry and agro-forestry; growing biomass for bioenergy production; harvesting technologies; transport system efficiencies and storage systems; scenario analysis
	Time status	ongoing
	Budget	internal program
	Website	
	Source	Wellisch (2010)

*	Name FA	**Natural Resources Canada (NRCan) (Ottawa, Ontario, Canada)**
	Name FP	Clean Energy Fund
	Main goal	Clean Energy Fund provides $850 M over five years for the demonstration of promising technologies, including large-scale carbon capture and storage (CCS) projects, and renewable energy and clean energy systems demonstrations. It also provides $150 M over five years for clean energy research and development (R&D). Bio is one of the areas funded. R&D component will fund a range of activities from basic research up to and including pre-demonstration pilot projects, in four areas. One area is: renewable and clean energy.
	Time status	2009-2014
	Budget	Total for bio $ unknown M
	Website	www.nrcan.gc.ca/eneene/science/ceffep-eng.php
	Source	Wellisch (2010)

*	Name FA	**Natural Resources Canada (NRCan) (Ottawa, Ontario, Canada)**
	Name FP	ecoENERGY Technology Initiative (ecoETI) - Bio Portfolio
	Main goal	The 4 year ecoENERGY Technology Initiative (ecoETI) funds RD&D to support the next generation energy technologies needed to break through to emissions-free fossil fuel production and use, as well as develop technologies for producing and using energy from other clean sources, such as renewables and bioenergy. Focus on GHG and air emissions reduction. The ecoETI "Bio-Based Energy Systems" portfolio is managed by CBIN and its objective is to harness the potential for bioresources to produce bioenergy, biofuels, industrial bioproducts and bioprocesses to help Canadian industry and communities meet clean air, efficiency and sustainability challenges.
	Time status	2008-2011
	Budget	$230 M (bio part $2 M)
	Website	
	Source	Wellisch (2009 & 2010); CBIN (2010); Natural Resources Canada (2010); Phillips (2007b); ecoETI projects (2010)

*	Name FA	**Natural Resources Canada (NRCan) (Ottawa, Ontario, Canada)**
	Name FP	Program for Energy Research & Development (PERD) - Bio Portfolio
	Main goal	The Program of Energy Research and Development (PERD) is a federal, interdepartmental program. PERD funds research and development designed to ensure a sustainable energy future for Canada in the best interests of both our economy and our environment. It directly supports energy R&D conducted in Canada by the federal departments and agencies, and is concerned with all aspects of energy supply and use. Research areas are: existing and new biomass supply; biomass conversion and utilization technologies; integrated bio-applications and cross-cutting activities (policy, sustainability). Managed by the Canadian Biomass Innovation Network (CBIN).
	Time status	ongoing program; 4 yr cycle (2009-2013)
	Budget	$2.5 M
	Website	
	Source	Wellisch (2009); PERD (2010); PERD projects (2010)

*	Name FA	**Natural Resources Canada (NRCan) (Ottawa, Ontario, Canada) – Office of Energy Research and Development (NRCan-OERD)**
	Name FP	Canadian Biomass Innovation Network (CBIN)
	Main goal	Coordinates the Federal Government's interdepartmental Research, Development and Demonstration (RD&D) activities in the area of bioenergy, biofuels, industrial biotechnology. CBIN R&D is divided into 4 Activities that have the following Themes: A1: Existing and New Biomass Supply • Detailed Agriculture and Forestry Biomass Inventory • Purpose-Grown Woody Biomass Production (forestry and agro-forestry) • Technologies for Harvesting, Preparation, Storage and Transportation • New and Improved Biomass Feedstocks This activity aims to improve the availability of Canada's two largest sources of biomass supply from forestry and agriculture operations. A2: Biomass Conversion and Utilization Technologies • Biomass Conversion to Heat and Power (Bioenergy) • Conversion of Waste to Bio-based Gases (biogas, syngas, hydrogen) • Key Separation and Conversion Processes for Bioproducts • Biocatalysis for Industrial Systems • Advanced Biomass Conversion and Utilization Technologies The intention here is to move viable technologies along the innovation curve. As these technology systems must be sustainable and competitive, attention is paid to increasing conversion and energy efficiencies to realize cost-effective and environmentally sound technological solutions. A3: Integrated Bio Systems • Integrated Biorefining (oilseeds, cereals, starch, forest fibre, agricultural fibre and mixed feedstock) • Regionally Clustered Enterprises Focus is on the entire process: from biomass feedstock to final products, by developing systems that produce bioenergy, biofuels, bio-based gases, chemicals and other high value co-products. A4: Cross-Cutting Activities Supports cross-cutting work related to coordination, strategy development, analysis and assessment, policy support, communication and dissemination.
	Time status	
	Budget	
	Website	www.cbin.gc.ca/index-eng.php
	Source	

*	Name FA	**National Science and Engineering Research Counsel (NSERC) (Ottawa, Ontario, Canada)**
	Name FP	Collaborative R&D Grants
	Main goal	CRD Grants support well-defined projects undertaken by university researchers and their private-sector partners. Direct project costs are shared by the industrial partner(s) and NSERC. Projects may range from one year to five years in duration, but most awards are for two or three years. CRD projects can be at any point in the R&D spectrum that is consistent with the university's research, training, and technology transfer mandate. Eligible collaborations include focused projects with specific short- to medium-term objectives, as well as discrete phases in a program of longer-range research. All proposals require evidence of detailed planning and sound budget justification, and must clearly spell out the underlying assumptions, intended approaches, milestones, and deliverables.

	Time status	up to 5 yrs
	Budget	total unknown: Average of $130k per year (up to 2:1 matching) - per project
	Website	www.nserc-crsng.gc.ca
	Source	Wellisch (2010); NSERC (2010a)
*	Name FA	**National Science and Engineering Research Counsel (NSERC) (Ottawa, Ontario, Canada)**
	Name FP	College and Community Innovation Program
	Main goal	The program provides funding to college and university faculty members, through defined stages, for research and development activities leading to technology transfer to a new or established Canadian company. Two distinct funding phases are proposed which are characterized by the maturity of the technology or the involvement of an early-stage investment entity or an industrial partner. These phases are limited in time. In the first phase, the direct costs of research will be entirely supported by NSERC; in the second phase, they will be shared with a private partner. The technology development may begin with a Phase I (Reduction-to-Practice Stage – i.e., demonstrating that the innovation is sufficiently tested and will work for its intended purpose) project followed by a Phase II (Technology Enhancement) project or, if the development is at a later stage, it can start directly with a Phase II project. In any case, a maximum of three years' funding will be available for any given project. 4 Canadian priority areas of research: environmental science and technologies; natural resources and energy; health and related life sciences and technologies; information and communications technologies; as well as in other areas of research that will advance the principles and goals of the Government of Canada's science and technology (S&T) strategy, Mobilizing Science and Technology to Canada's Advantage.
	Time status	Entry level (two years); other level (up to five years)
	Budget	total unknown: entry level (up to $100k per year); other level (up to $500k per year in yr 1-3, 80% of base funding in yr 4-5) - per project
	Website	www.nserc-crsng.gc.ca
	Source	Wellisch (2010); NSERC (2010b)
*	Name FA	**National Science and Engineering Research Counsel (NSERC) (Ottawa, Ontario, Canada)**
	Name FP	Idea to Innovation (I2I)
	Main goal	The program provides funding to college and university faculty members, through defined stages, for research and development activities leading to technology transfer to a new or established Canadian company. Two distinct funding phases are proposed which are characterized by the maturity of the technology or the involvement of an early-stage investment entity or an industrial partner. These phases are limited in time. In the first phase, the direct costs of research will be entirely supported by NSERC; in the second phase, they will be shared with a private partner. The technology development may begin with a Phase I (Reduction-to-Practice Stage – i.e., demonstrating that the innovation is sufficiently tested and will work for its intended purpose) project followed by a Phase II (Technology Enhancement) project or, if the development is at a later stage, it can start directly with a Phase II project. In any case, a maximum of three years' funding will be available for any given project.
	Time status	phase I (up to one year); phase II (up to two years)
	Budget	total unknown; phase I (up to $125k): phase II (up to $350k) - per project
	Website	www.nserc-crsng.gc.ca
	Source	Wellisch (2010); NSERC (2010c)

*	Name FA	**National Science and Engineering Research Counsel (NSERC) (Ottawa, Ontario, Canada)**
	Name FP	Industrial Research Chair (IRC)
	Main goal	An IRC grant provides funding for the salary of the Chairholder, infrastructure, research tools and instruments, and general expenses related to the Chair's program of research. Chairholders are expected to focus their activities on conducting research and training highly qualified personnel, while carrying a reduced administrative and teaching load. IRCs are funded jointly by NSERC and industry. Provincial or federal government departments and agencies may also co-sponsor/support an IRC, but only the industrial contributions are taken into account when NSERC determines its funding level.
	Time status	5 yrs and renewable
	Budget	total unknown; $750k and up (1:1 matching) - per project
	Website	www.nserc-crsng.gc.ca
	Source	Wellisch (2010); NSERC (2010d)

*	Name FA	**National Science and Engineering Research Counsel (NSERC) (Ottawa, Ontario, Canada)**
	Name FP	Forest Sector R&D Initiative
	Main goal	NSERC Forest Sector R&D Initiative aims to identify commercially relevant research programs that will create new market opportunities for the Canadian forest sector. The objective is to come up with innovative products and to increase investment in a higher-value-added forest sector. The FPInnovations Flagship Innovation Program contains 5 research themes: Next Generation Building Solutions; Next Generation Pulps and Papers; Energy and chemicals from Forest Biomass; Novel Bioproducts from Forest Biomass; Integrated Value Maximization.
	Time status	5 years
	Budget	$34 M
	Website	www.nserc-crsng.gc.ca
	Source	Wellisch (2010); NSERC (2010e)

*	Name FA	**National Science and Engineering Research Counsel (NSERC) (Ottawa, Ontario, Canada)**
	Name FP	Strategic Network Grant
	Main goal	Strategic Network Grants fund large-scale, multi-disciplinary research projects in targeted research areas that require a network approach and that involve collaboration between academic researchers and Canadian-based organizations. The applicant should be an established researcher with a solid track record in collaborative research, student training and grant management, and who demonstrates the leadership and other skills necessary for managing a complex, interdisciplinary, multi-institutional project.
	Time status	5 years
	Budget	total unknown: $5 M over 5 yrs (per project)
	Website	www.nserc-crsng.gc.ca
	Source	Wellisch (2010); NSERC (2010f)

*	Name FA	**National Science and Engineering Research Counsel (NSERC) (Ottawa, Ontario, Canada)**
	Name FP	Strategic Project Grant (SGP)
	Main goal	The SPG Program funds early-stage project research in targeted areas that could strongly enhance Canada's economy, society and/or environment within the next 10 years. Seven strategic target areas: Advanced Communications and Management of Information; Healthy Environment and Ecosystems ; Sustainable Energy Systems (Production, Distribution and Utilization); Biomedical Technologies; Competitive Manufacturing; Quality Foods and Novel Bioproducts; Safety and Security.
	Time status	Up to 3 years
	Budget	total unknown; Approximately $400k over 3 yrs (per project)
	Website	www.nserc-crsng.gc.ca
	Source	Wellisch (2010); NSERC (2010g)

*	Name FA	**National Science and Engineering Research Counsel (NSERC) (Ottawa, Ontario, Canada)**
	Name FP	Strategic Workshop Grant (SWP)
	Main goal	The SWP is intended to fund workshops for building new collaborations between Canadian academic researchers and the industry and government receptor community. The program is primarily intended to seed new collaborations in the areas of research targeted by the Strategic Project Grants (SPG) and the Strategic Network Grants (SNG) programs, yet does not exclude other fields of research supported by NSERC. SWP is a three-year pilot initiative. Workshops are intended for small, highly focused groups, with attendance not expected to exceed 20 participants. An award may support Canadian and foreign participation, but the workshops must be held in Canada. Funds may be used to organize a single workshop or several events of more limited participation.
	Time status	
	Budget	total unknown; 25k per project
	Website	www.nserc-crsng.gc.ca
	Source	Wellisch (2010); NSERC (2010h)

4.3 Research organisations Canada

*	Name	**Agricultural Biorefinery Innovation Network for Green Energy, Fuels & Chemicals (ABIN) (Ottawa, ON, Canada)** Led by the University of Western Ontario. The network includes Agri-Therm Ltd., Ecole Polytechnique de Montreal, Perth Community Futures Development Co., Ryerson University, the Saskatchewan Research Council, StormFisher Ltd., the University of Alberta, the University of British Columbia, the University of Guelph, the University of Manitoba, the University of Northern British Columbia, the University of Saskatchewan, the University of Sherbrooke and the University of Toronto.
	Main goal	The Agricultural Biorefinery Innovation Network for Green Energy, Fuels and Chemicals (ABIN) involves top Canadian university researchers, government experts and the private sector working collaboratively to design and optimize processes that will convert renewable biomass into value-added bio-based products. The network's multi-disciplinary team of experts will build sustainable pathways that will put Canada at the forefront in the development of cutting-edge technologies leading from feedstock enhancement through to output of green energy, fuels and chemicals, and on to practical application via commercialization. ABIN focuses on under-utilized biomass resources, such as residues from agricultural harvests, as well as on specialized crop development. Together with development of novel biorefinery processes, these resources have the conversion potential to push Canada towards meeting its international climate change commitments, and to stimulate economic growth, especially in rural Canada.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	2009 - now
	Budget	
	Website	
	Source	ABIP (2010)

*	Name	**Alberta BioPlastics Network (Edmonton, AL, Canada)** Centred at the University of Alberta
	Main goal	The Alberta BioPlastics Network (ABN) is a multi-institutional research network. Its mandate is to engage in activities to promote the use of Alberta's agricultural commodities as feedstock for the production of specialty chemicals and polymers, and significant efforts are currently underway to commercialize the technology that has been created. The institutions that participate in the ABN are: • University of Alberta • Alberta Agriculture, Food and Rural Development • Alberta Research Council • Agriculture and Agri-Food Canada • Alberta Economic Development Environment Canada • Alberta Canola Producers Commission
	Type BR	
	Time status	2003 - now
	Budget	
	Website	www.ualberta.ca
	Source	Philips (2007a); Bioplastics

* Name **Alberta Flagship Initiative: Lignocellulosic BioConversion (Edmonton, AL, Canada)**
Main goal Focus on improved conversion methods for fibrous biomass. Find and develop new/optimized enzymes and fermentation microbes from novel sources or design.
Type BR Lignocellulosic feedstock biorefinery
Time status
Budget
Website
Source Philips (2007a)

* Name **BIOCAP (Ottawa, Ontario, Canada)**
Main goal This was a research foundation that, with fundings from various stakeholders including government ministries, directed research programs towards sustainable and clean energy. Activities have been stopped.
Type BR
Time status 1998 - 2008
Budget $8 M in 10 years
Website www.biocap.ca
Source Philips (2007b)

* Name **BioteCanada (Ottawa, Ontario, Canada)**
Main goal BIOTECanada is dedicated to the sustainable commercial development of biotechnology innovation in Canada. It is the national industry-funded association with over 250 member companies representing the broad spectrum of biotech constituents including emerging and established firms in the health, industrial, and agricultural sectors, as well as academic and research institutions and other related organizations.
Type BR
Time status 1987 - now
Budget
Website www.biotech.ca/en/default.aspx
Source Philips (2007b)

* Name **BioPotato Network: a Canadian network for potato-based bioproducts (BioPotato) (Ottawa, ON, Canada)**
Main goal Scientists from government, universities and industries across Canada have joined forces to form the BioPotato Network. Their focus is to develop potato-based bioproducts that are beneficial to the health of Canadians and to the environment. That means e.g. value added uses for the potato, health and pharmaceutical products, dietary properties, potato-based plastics and biopesticides for insect control. The BioPotato Network will focus on five areas of research that will give potato farmers a competitive edge and improve their bottom line:

- Commercializing Potato Extracts -Extracts from potatoes can be turned into functional food and nutraceutical products with the potential to provide health benefits beyond basic nutrition. Scientists will search for more of these extracts and develop ways to commercialize these discoveries, including new processing methods.
- Healthier Potato Varieties - Researchers will develop new potato varieties that provide consumers with greater control over their diet and health, including varieties with lower Glycemic levels that would allow diabetics to add potatoes to their diets without the fear of a rapid elevation of their blood sugar levels.
- Pharmaceutical Uses - Researchers will investigate new ways to use starch and

other compounds in potatoes as additives in the processed food, cosmetics and pharmaceutical industries.
- New Generation of Bioplastics - Potato starch-based polymers and blends are currently used to make bioplastic, a new generation of material that can reduce the environmental impact of plastics. Scientists will work on improving potato-based bioplastics to make them stronger and easier to use.
- Biopesticides for Insect Control - Some wild potato relatives contain a natural resistance to insects. Researchers will identify these resistance traits and breed them into new potato varieties, reducing the need for chemical insect control.

Type BR Whole crop birefinery
Time status
Budget $5.3 M (ABIP)
Website
Source Wellisch (2009); ABIP (2010)

* Name **Canadian Forest Innovation Council (CFIC) (Ottawa, ON, Canada)**
Main goal The Canadian Forest Innovation Council, CFIC, is a group of 11 senior decision makers in the Canadian Forest sector who formally represent the three major constituencies that fund forest sector innovation: the Government of Canada, the provinces, and industry. Representation is at the CEO, Deputy Minister, and Assistant Deputy Minister level.
They sponsored a series of White Papers on transformative technologies for the forest industry. Three of them dealt in one way or another with the concept of biorefinery:
- Transformative technologies for the forest sector: Bioenergy production in Canada
- Transformative technologies for Biochemicals
- Transformative technologies for Pulp and paper

Type BR Lignocellulosic feedstock biorefinery
Time status 2006
Budget
Website
Source Towers et al. (2006); CFIC (2006a); CFIC (2006b)

* Name **Canadian University Forest Biorefinery Network (CUFBNet) (Vancouver, BC, Canada)**
Main goal CUFBNet is a voluntary associative network of scientists from Canadian Universities and FPInnovations engaged in cooperative biorefining R&D work. CUFBNet will provide an organisational structure for information sharing, coordination and cooperation between research groups and development of partnerships with research institutes and industry. CUFBNet will secure adequate funding for its autonomous operation. It is not intended however that CUFBNet become an R&D granting agency at any time.
Twelve identified RD&D Program Domains:
1. Product opportunity analysis
2. Forest feedstocks
3. Thermochemical pathways
4. Bioproducts from effluent and solid wastes
5. Products from hemicellulose
6. Products from lignin
7. Products from extractives
8. Products from condensates
9. Phyto-chemical products from bark, branches and foliage
10. Integrating novel products with existing product lines

11. Conversion of uncompetitive pulp mills
12. Integrating pulp mills with other industries

Type BR	Lignocellulosic feedstock biorefinery
Time status	2006 - now
Budget	
Website	
Source	PAPIER (2009); Towers et al. (2007)

* Name **Canadian Triticale Biorefinery Initiative (CTBI) (Ottawa, ON, Canada)**

Main goal	The Canadian Triticale Biorefinery Initiative (CTBI) is a Canada-wide network of institutions, technology experts and industries that will develop all aspects of triticale for its use as an industrial crop and biorefinery feedstock. Triticale, a hybrid of wheat and rye, is a source of carbohydrates (e.g. starch, cellulose, hemicellulose) that can be used to produce chemicals and fuels derived from simple sugar chemistry. It is also considered to be a competitive source of fibre and raw biomass. With crop modifications and the development of advanced processing technologies, triticale will provide new values as a renewable resource for chemicals, fuels and materials. Triticale is a platform upon which a comprehensive range of biorefining technologies can be built. The CTBI vision is to develop "industrial designer" triticale as the most important major new crop in Western Canada and a highly valued renewable source of feedstocks and biomaterials for the Canadian manufacturing industry. 30 R&D projects with six strategic priorities for triticale.
Type BR	Lignocellulosic feedstock biorefinery; Whole crop biorefinery
Time status	2006-2016
Budget	$15.5 M (ABIP)
Website	www.ctbi.ca
Source	Bioref-Integ (2010)-p54; Wellisch (2009); ABIP (2010)

* Name **Canadian Wood Fibre Centre (Ottawa, ON, Canada)**

Main goal	The Canadian Wood Fibre Centre (CWFC) brings together forest sector researchers to develop solutions for the Canadian forest sector's wood fibre related industries in an environmentally responsible manner. Its mission is to create innovative knowledge to expand the economic opportunities for the forest sector to benefit from Canadian wood fibre. It focuses on improving forest productivity and fibre quality as well as increasing the value of the forest resource.
Type BR	Lignocellulosic feedstock biorefinery
Time status	
Budget	
Website	cfs.nrcan.gc.ca/subsite/cwfc
Source	Canada Forests (2010)

* Name **Cellulosic Biofuels Network (CBN) (Ottawa, ON, Canada)**

Main goal	CBN is a Canadian network of more than 40 government and university scientists seeking to eliminate constraints for the Canadian bioethanol industry. The network's goal is to provide Canada with a low-cost economic and environmental plan for ethanol production based on food-crop residues, dedicated biomass crops and the use of marginal lands. Research within CBN will: 1. Evaluate and enhance cellulosic biomass potential (biomass yield, agronomic innovations, energy balance of crop residues, dedicated biomass crops on marginal land, harvesting, compaction, transport strategies, cost to the factory); 2. Evaluate and design new physical, chemical and enzymatic technologies

for deconstruction of plant cell walls;
3. Reduce enzymatic deconstruction cost: select or engineer plants with increased ability for cell wall deconstruction (modifying cell wall biosynthesis, expressing cell wall degrading enzymes, selecting tailored cocktails of enzymes for each biomass source);
4. Select or engineer new generation fermentation yeast (increased ability for fermentation, reduced fermentation inhibition, ability to degrade cellulose);
5. Evaluate overall economic, environmental, and social cost of producing cellulosic ethanol.

Type BR: Lignocellulosic feedstock biorefinery
Time status:
Budget: $19.9 M (ABIP)
Website:
Source: Wellisch (2009); ABIP (2010)

* Name: **CRIBE (Ottawa, ON, Canada)**
Main goal: CRIBE was established in 2009 by the Province of Ontario. CRIBE is a not-for-profit organization developed by the Ontario Ministry of Research and Innovation, focuses on commercializing new forest products and technologies by working with leading researchers and industry. CRIBE has to bring business, government and communities together to develop new economic opportunities and to help ensure the future of Northern Ontario. CRIBE seeks out partnerships with entrepreneurs, research organizations and industry with the specific purpose of turning existing research and ideas into a commercial reality.
Type BR:
Time status: 2009 - now
Budget:
Website:
Source: CRIBE (2009b)

* Name: **Ecole Polytechnique Montréal (Montréal, QC, Canada), NSERC Environmental Design Chair**
Main goal: Systematic approach to address forest biorefineries opportunities, built on the definition of a methodology to drive the biorefinery decision making with particular attention given to product and process design.
Type BR: Lignocellulosic feedstock biorefinery
Time status:
Budget:
Website: www.polymtl.ca
Source: NSERC (2010)

* Name: **Feed Opportunities from the Biofuels Industries (FOBI) (Ottawa, ON, Canada)**
Main goal: The Feed Opportunities from the Biofuels Industries (FOBI) network is a multidisciplinary initiative composed of private, public and academic members aimed at revitalizing economic activity in rural Canada. FOBI will explore the integration of livestock production and wheat-based ethanol production, with a focus on creating novel co-products and new markets for existing co-products. FOBI will analyze economic and policy issues involved in integrating the ethanol sector with other agricultural industries. It will evaluate the current steps in the ethanol process, model energy, nutrient flow and lifecycle analysis, as well as the impact of feed constituents and functionality of those constituents in domestic and international markets. New wheat varieties, optimized for wheat-based ethanol will be evaluated and advanced. FOBI will improve the economics and environmental

		interface of livestock operations through nutritional evaluation and development of feeding recommendations and nutrient management for wheat-based co-products. While wheat-based ethanol production is the primary focus, some parallel work is being done on other biofuels, such as biodiesel and cellulose technologies. FOBI is currently linked with the Cellulosic Biofuel Network (CBN) as their animal feeding platform, and there is opportunity for network expansion into additional alternate biofuels systems.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	$6 M (ABIP)
	Website	
	Source	Wellisch (2009); ABIP (2010)
*	Name	**FPInnovations (Pointe-Claire, QC, Canada)**. Formed in April 2007 when Canada's three forest research institutes merged (FERIC, Forinteck and Paprican)
	Main goal	FPInnovations is Canada's leading not-for-profit forest products research institute which performs research, technical services and tech transfer activities relating to wood harvesting, wood products, pulp and paper, nanotechnology and bio-energy and chemical production. FPInnovations' staff numbers more than 600. Its research laboratories are located in Québec City, Montréal and Vancouver, and it has technology transfer offices across Canada. Harmonize forest research, integrate innovation along the value chain and support industry renewal in the short term and diversification in the long term.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	2007 - now
	Budget	
	Website	www.fpinnovations.ca
	Source	Canada Forests (2010); FPInnovations (2009)
*	Name	**Industrial Oil Seed Network (IOSN) (Ottawa, ON, Canada)**
	Main goal	The Industrial Oil Seed Network (IOSN) will develop new oilseeds to substitute for petroleum in a variety of applications and support the use of bio-based fluids to replace petroleum in selected markets. This research will provide biodegradable, renewable substitutes for petroleum in specific applications and measure the environmental benefits of these products. IOSN research and development will increase the price Canadian farmers receive for their oilseeds while at the same time decrease our carbon footprint by replacing petroleum in various usage areas. The network will apply tribology (the study of lubrication and how materials wear) in collaboration with Canadian experts in oilseed biology and American experts in formulating soybean oil for industrial purposes. This unique group of expertise is focused on improving the ability of Canadian oilseeds to substitute for petroleum in various non-fuel applications. Network program initiatives include an investigation by Toronto Community Housing into how bio-based fluids can lessen community housing's impact on the urban environment. For example, replacing petroleum products used in elevators with vegetable based, bio-degradable hydraulic fluids is an option currently under consideration. In Nova Scotia, Prince Edward Island and New Brunswick, a similar initiative will support early adopters seeking to replace petroleum products in the construction industry and in civic and marine transportation. The program has a wide scope and will continue to find, identify and support early adopters of bio-based industrial fluids. These initiatives will increase the value of oilseeds and explore economic development opportunities for the rural environment including blending, packaging and distribution of bio-based products. The IOSN welcomes industrial users of lubricants, transportation fuel additives, greases and related

		products to contact us directly to discuss opportunities to field test bio-based products.
	Type BR	Oilseed biorefinery
	Time status	
	Budget	$3 M (ABIP)
	Website	
	Source	Wellisch (2009); ABIP (2010)
*	Name	**Lakehead University (Thunder Bay, ON, Canada) – The Biorefining Research Initiative (BRI)**
	Main goal	The goal of the Biorefining Research Initiative (BRI) is to create a world-class centre of excellence dedicated to developing transformative technologies and products based upon biomass from the Boreal Forest. The BRI is not limited to only biofuels, chemicals and bioenergy from forest biomass, but will also consider the economic benefits derived from the forest ecosystem. The focus is on three major topics: • Bioconversion: conversion of cellulose in forest biomass into biofuels (ethanol, methane), and other bio-based chemicals, bioenergy (biomass as an energy source in power generation). • Chemical conversion: production of low-valued, high-volume commodity chemicals from forest biomass by thermochemical processes. • Natural Bioproducts from the Boreal Forest such as the microbiota: high-valued chemicals including pharmaceuticals, enzymes and microbial agents for bioremediation.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	2008 - now
	Budget	
	Website	lubri.lakeheadu.ca
	Source	BRI (2010)
*	Name	**Lipid Products Research Alberta (LiPRA) (Edmonton, AL, Canada)** Centred at the University of Alberta
	Main goal	The general theme of my research is the development of novel analytical methods to solve emerging problems in lipid chemistry, food science, sensory science, or analytical challenges with nutraceuticals or natural products in general. Particular emphasis will be given to the development of methods which improve accuracy in the quantification of lipids.
	Type BR	Oilseed biorefinery
	Time status	
	Budget	
	Website	
	Source	Philips (2007a); LiPRA research
*	Name	**Natural Fibres for the Green Economy Network (NAFGEN) (Ottawa, ON, Canada)**
	Main goal	• Breeding and development of biorefinery conversion technologies to produce materials and chemicals from multiple purpose crops: oilseed flax and industrial hemp. The Natural Fibres for the Green Economy Network (NAFGEN) brings together a significant portion of Canada's relevant innovative capacity to tackle the issues and challenges in developing a Canadian natural fibres value chain, from feedstock production through to the development and delivery of bioproducts (materials, chemicals, and energy) to market. NAFGEN has adopted an outcome-based philosophy with a whole crop utilization strategy at its core, which is firmly

grounded in creating value at three different steps of the value chain:

1. the farm gate value for Canadian farmers realized from bast fibre crops (flax and hemp);
2. new high quality job opportunities in rural regions;
3. new opportunities in the Canadian manufacturing sector.

Challenges and barriers to be directly addressed by NAFGEN include breeding, straw management, lack of agronomic information for the production of natural fibres, under-developed bioresource engineering, current issues in the reliability of fibre crops (availability of natural fibre feedstocks), issues in the grading of fibres, the need for novel conversion technologies, the need for the integration of suites of conversion technologies in natural fibre-based biorefinery models, the need for the development of new products (materials, chemicals, energy/fuels), the need to identify, engage, and cultivate corporate partners to both commercialize Canadian natural fibre-based bioproducts and to gain acceptance in the receptor markets for these products, and the need for whole system design and analysis based on principles of sustainability.

Type BR	Lignocellulosic feedstock biorefinery
Time status	
Budget	$9 M (ABIP)
Website	
Source	Wellisch (2009); ABIP (2010)

* Name **NRC - Biotechnology Research Institute (Montréal, Quebec, Canada)**

Main goal	In the Environment Program, NRC-BRI's researchers investigate the issues of bioremediation, water quality, and sustainable development.
Type BR	
Time status	
Budget	
Website	
Source	Philips (2007b); NRC-BRI (2010)

* Name **NRC - Industrial Materials Institute (NRC-IMI) (Boucherville, Quebec, Canada)**

Main goal	NRC-IMI is promoting the growth and competitiveness of Canadian industry through research and development in materials processing technologies.
Type BR	
Time status	
Budget	
Website	
Source	Philips (2007b); NRC-IMI (2010); NRC-IMI competitive materials manufacturing

* Name **NRC - Plant Biotechnology Institute (Saskatoon, Saskatchewan, Canada)**

Main goal	NRC-PBI is dedicated to improving Canadian crops to benefit the Canadian economy. We perform and promote research and innovation that improves plant biotechnology methods and adds value and quality to Canadian crops to keep our agricultural sector strong and competitive.
Type BR	Whole crop biorefinery
Time status	
Budget	
Website	
Source	Philips (2007b); NRC-PBI (2010);

* Name **Pulse Research Network (PURENet) (Ottawa, ON, Canada)**

Main goal The Pulse Research Network (PURENet) is a collection of scientists, researchers and industry personnel whose vision is to achieve a thriving and prosperous Canadian bioeconomy. PURENet is driven by innovative scientific solutions to deliver sustainable, environmentally friendly and functionally superior food, thereby contributing to the well-being of all Canadians.
PURENet will develop and expand the use of pulses, based on their unique and inherent attributes, by conducting research in three areas - bioproduct development, sustainable production of crops and feed development. This research will focus on demonstrating the health and nutritional benefits of foods containing pulses. Results could include the incorporation of pulse-based diets into healthy living guidelines to manage important health conditions faced by many Canadians. PURENet will also improve the science of pulse crop breeding through the enhancement of plant varieties by adding nutrients to existing crop varieties. Another initiative will examine the possible use of pulses in the development of nitrogen forms that can be used in crop planting.
The economic, social and environmental benefits associated with producing pulse crops are substantial and PURENet will strive to enhance return on investment throughout the entire agri-food value chain.

Type BR Whole crop biorefinery

Time status

Budget

Website

Source ABIP (2010)

* Name **Ryerson University (Toronto, Ontario, Canada) – Department Green fuels and renewable energy**

Main goal Research on creating a sustainable biorefinery that utilizes domestically produced agricultural crops and wastes to produce value added biobased products, such as, green chemicals and fuels, and green and renewable energy. This includes assembling and integrating a range of process technologies to make optimal use of, and to improve sustainability of Canadian agricultural resources.

Type BR Lignocellulosic feedstock biorefinery

Time status

Budget

Website www.ryerson.ca

Source Dept Green Fuels and Renewable Energy

* Name **Sustainable Cropping System Platforms for Biodiesel Feedstock Quantity and Quality (SBQQ) (Ottawa, ON, Canada)**

Main goal The Sustainable Cropping System Platforms for Biodiesel Feedstock Quantity and Quality (SBQQ) network brings together a wide array of agricultural professionals to obtain readily transferable canola production knowledge. This knowledge will then be used to ensure that the biodiesel industry in Canada and abroad has adequate Canadian-grown feedstock for high quality biodiesel production. Producing crop oil to ensure a dependable and high quality feedstock is the very basis of the biodiesel industry. With many new facilities coming into production in the biofuels industry, feedstock supply failures would be disastrous. The SBQQ network addresses questions to help crop producers increase canola and alternative oilseed production.
These key questions include:

1. What are the agronomic and economic implications of growing canola more frequently in rotations? How important is crop sequence on canola yield and quality?

2. Can canola be grown continuously if we rotate cultivars over years or grow mixtures of canola cultivars?
3. Will high input levels lead to increased canola yields that are profitable to the farmer?
4. Are there oilseed species other than canola that would be suitable for biodiesel?
5. How is canola oil and biodiesel quality influenced by agronomic management, soil type, and environmental conditions?
6. What are the implications of these oil quality effects on high quality food markets and the developing biodiesel industry?

Type BR	Oilseed biorefinery
Time status	
Budget	
Website	
Source	ABIP (2010)

* Name **University of Western Ontario (Ilderton, ON, Canada) – Institute for Chemicals and Fuels from Alternative Resources (ICFAR)**

Main goal	The Institute for Chemicals and Fuels from Alternative Resources, ICFAR, is a research institute within the Faculty of Engineering at The University of Western Ontario. The focus of ICFAR is to conduct fundamental and applied research and development activities in the fields of renewable energy, valorisation of residues for the production of renewable fuels and chemicals, environmental protection and sustainability. State-of-the-art facilities and laboratory infrastructure, including several pilot plants and demonstration units.
Type BR	Lignocellulosic feedstock biorefinery
Time status	2008 - now
Budget	In March of 2008, Ontario invested $5 million to support the design, construction and initial start-up operation of ICFAR's new 20,000-square-foot research centre.
Website	www.eng.uwo.ca/icfar
Source	ICFAR research focus

4.4 Pilots plants Canada

*	Name	**Enerkem (Montréal, QC, Canada)**
	Name pilot	Enerkem Sherbrooke Pilot Plant and Research Facility
	Description	Gasification and catalytic synthesis. Operating since 2003. Ethanol capacity of 475,000 litres.
	Feedstock	Tested 20 different feedstocks such as Municipal Solid Waste, forest residues, straw, spent plastics construction and demolition wood, treated wood
	Products	Second-generation ethanol, syngas, and methanol
	Type BR	Syngas biorefinery for second generation ethanol and green chemicals
	Time status	
	Budget	
	Website	www.enerkem.com
	Source	Bioref-Integ (2010)-p64; Wellisch (2009)

*	Name	**Enerkem (Montréal, QC, Canada)**
	Name pilot	Enerkem Westbury Industrial Demonstration Plant
	Description	Gasification and catalytic synthesis. Operating since 2009. Ethanol capacity of 5 million litres.
	Feedstock	Decommissioned electrical poles, forest residues, selected MSW
	Products	Second generation ethanol, green chemicals, such as: methanol, acetic acid and acetates
	Type BR	Syngas biorefinery for second generation ethanol and green chemicals.
	Time status	
	Budget	
	Website	www.enerkem.com
	Source	Bioref-Integ (2010)-p64; Wellisch (2009)

*	Name	**Ensyn Technologies Inc. (Ottawa, ON, Canada)**
	Name pilot	Thermal conversion of forestry residue to liquid fuels. Commercial site.
	Description	Ensyn's research and development efforts revolve around Ensyn's three main product groups: • In the bio-energy sector, where Ensyn's products are well developed, R&D activities focus on assisting in deploying bio-energy technologies at customer sites, and in the reduction of market entry barriers. • In the bio-chemical sector, R&D activities focus on assisting in the rollout of existing product lines, and in the reduction of market entry barriers. R&D is also undertaken to commercialize new bio-chemical products based upon identified markets. • In the renewable transportation fuel sector, R&D is undertaken in conjunction with strategic corporate or national lab partners on commercializing Ensyn's product line.
	Feedstock	Forestry residue; Residual woody biomass from a hardwood flooring plant and sawmill
	Products	Food (flavourings), polymers (resins), heat, electricity plus (in the future) synthetic biofuels (upgraded bio-oil)
	Type BR	Thermochemical pathway / syngas platform biorefinery; Pyrolytic liquid biorefinery for food flavourings, polymers, fuels and heat from lignocellulosic residue
	Time status	
	Budget	
	Website	www.ensyn.com
	Source	Philips (2007b); IEA Task 42 (2009)

*	Name	**Highmark Renewables (Vegreville, AB, Canada)**
	Name pilot	Hairy Hill Integrated bioRefinery™
	Description	Integrated livestock production and ethanol plant.
	Feedstock	Manure; wheat
	Products	Biogas/electricity and fertilizer from manure. Ethanol and animal feed from wheat
	Type BR	
	Time status	Construction 2010-2011
	Budget	
	Website	www.highmark.ca
	Source	Wellisch (2009); Hairy Hill project
*	Name	**Iogen (Ottawa, Ontario, Canada)**
	Name pilot	Iogen Corporation demonstration plant Ottawa
	Description	Fractionation, enzymatic hydrolysis and ethanol fermentation of wheat straw to produce cellulosic ethanol. Began in 2004. Size 30 tonnes/day feedstock and 2 million litres of ethanol per year.
	Feedstock	Straw
	Products	Cellulosic ethanol, electricity, lignin
	Type BR	C6/C5 sugars and lignin biorefinery for bioethanol and chemicals.
	Time status	
	Budget	
	Website	www.iogen.ca
	Source	Bioref-Integ (2010)-p64; Wellisch (2009)
*	Name	**Lignol (Burnaby, BC, Canada)**
	Name pilot	Lignol Innovations Corporation pilot plant
	Description	Organosolv-based fractionation and hydrolysis, enzymatic saccharification and fermentation. This pilot adapted the ethanol-based organosolv process to produce fuel ethanol, high purity lignin and co-products (furfural and wood extractives) from lignocellulosic feedstocks (forest, agriculture). It received US DOE funding for commercial scale demonstration plant.
	Feedstock	Wood, straw
	Products	Cellulosic ethanol, lignin, acetic acid, furfural and xylose
	Type BR	C6/C5 sugars and lignin biorefinery for bioethanol, chemicals and biomaterials
	Time status	
	Budget	
	Website	www.lignol.ca
	Source	Bioref-Integ (2010)-p64; Wellisch (2009); Lignol (2009)
*	Name	**Forestry Biorefinery (Thunder Bay, ON, Canada)**
	Name pilot	
	Description	The initial phase of the pilot project involves a feasibility study that will provide a complete analysis of the biorefinery's functions, including a pre-commercial process to extract wood fibres; identify market opportunities; assess output capacity of the demonstration plant; and determine full project costs.
	Feedstock	Forest biomass
	Products	Energy and next-generation forest products
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	2010 - now
	Budget	$ 20 M (Federal Government & Province of Ontario)
	Website	
	Source	Foresttalk (2009)

*	Name	**Syntec Biofuels Inc. (Vancouver, BC, Canada)**
	Name pilot	
	Description	Gasification, catalytic synthesis and steam reforming used to convert forest and agricultural residues into methanol and ethanol – Syntac B2A technology.
	Feedstock	Wood, energy crops, agriculture residues.
	Products	Ethanol, methanol, n-butanol and n-propanol
	Type BR	Syngas biorefinery for second generation ethanol and green chemicals
	Time status	
	Budget	
	Website	www.syntecbiofuel.com
	Source	Bioref-Integ (2010)-p64; Wellisch (2009)

5 Australia

5.1 Introduction

Rowlands et al. (2008) describe the specific Australian biorefinery challenges and opportunities. Australia has a large geographic area and low overall population density. The country relies heavily on transport services to maintain its economy. Alternative sources of fuels derived from biomass must be found. An Australian challenge is to develop integrated systems that avoid transporting bulky and water-rich biomass over long distances to processing plants and that take account of scarce water resources and fragile ecosystems. An opportunity is to reforest cleared land through selective, managed planting of salt bush or salt-tolerant deep-rooted trees. Compact modular super- or near-critical processing technology is potentially well suited due to its relatively low capital costs, small size, and (potentially) transportable nature. This way biomass could be converted to more readily transportable liquid fuels or intermediates of higher energy density. Parts of Australia offer favourable conditions (abundant sunlight and warmth) for cultivating algae as a triglyceride feedstock for biodiesel production. Challenges are co-location of CO_2 sources and designing suitable reactor and pond systems.

Figure 4 Map of Australia (source: www.mapsofworld.com/australia-political-map.htm).

Australian advantages are an advanced agriculture (and potential downstream processing capability), diversity of crops and growing seasons and a strong R&D and regulatory infrastructure (CSIRO, 2008; Haritos, 2007). In Australia there are moratoria in most states on

the production of genetically modified crops. Therefore, production of biobased materials via genetically-modified crops may not be an option (Haritos, 2007).

According to Haritos (2007) there is substantial biobased products research and development activity in Australia. However, in 2007 the small Australian industry was still lagging behind other developed countries in terms of innovation and product range, and was mostly centred around biobased food packaging products (such as novel biodegradable polymers). According to O'Connel et al. (2007) rudimentary biorefineries have been established mainly around ethanol production for biofuels or bio-oils from wood. In 2007 Australia had not yet formed a national vision for production, development and manufacture of biobased products. Research gaps that have been identified for biobased products in Australia are (Haritos, 2007):

- on-going demand for new and innovative biobased products having desirable attributes for industry, including low energy costs of production;
- routes to high purity, cost-effective production of the raw materials for biobased products;
- cost-effective methods of downstream biomass processing to enrich biobased product fractions;
- maximize financial return from processing of biomass containing primary trait of interest and reduce waste;
- documented claims of environmental sustainability for biobased products;
- fulfil regulatory requirements for the production of biobased feedstock;
- for novel biobased products, identify characteristics and potential markets;
- communication strategies to inform stakeholders of the benefits of biobased products to the environment, sustainable agriculture and rural economies;
- build research capacity in discovery, production and development of biobased products and facilitate commercialization of new products in Australia.

In her report Haritos (2007) distinguishes between Australian research and development in biobased products from four different sources:

- sugarcane;
- grain, oilseed and other crops;
- wood and forestry waste;
- fermentation.

According to O'Connell et al. (2007) there is active Australian research and development into bioproducts and biorefineries, supported by the Research and Development Corporations and the Cooperative Research Centre schemes. The research and development covers the full range of activities from investigation of agronomic characteristics, of activities from investigation of agronomic characteristics of new industrial crops, examination of value chains for bio-based materials and development of novel materials from agricultural by-products and high value products from existing plants and genetically engineered varieties. In a survey among stakeholders the area of conversion technologies was the most numerously identified area of research focus. Aspects of this research area are e.g. developing the technologies needed to derive ethanol from feedstocks (primarily mentioning lignocellulosics), the recovery and use of secondary products, reduction of cost of production and integrating bioenergy into the farming systems.

5.2 Funding programmes Australia

*	Name FA	**AusBiotech (Melbourne (Melvern), VIC, Australia)**
	Name FP	
	Main goal	AusBiotech is Australia's Biotechnology Industry Organisation, which represents over 3,000 members, covering the human health, agricultural, medical device, bioinformatics, environmental and industrial sectors in biotechnology.
	Time status	
	Budget	
	Website	www.ausbiotech.org
	Source	Industrial Biotechnology
*	Name FA	**Australian Research Council (ARC) (Canberra, NSW, Australia)**
	Name FP	National Competitive Grants Program (NCGP)
	Main goal	The ARC is a statutory authority within the Australian Government's Innovation, Industry, Science and Research (IISR) portfolio. The ARC provides advice to the Government on research matters and manages the National Competitive Grants Program (NCGP), a significant component of Australia's investment in research and development. Through the NCGP, the ARC supports the highest-quality fundamental and applied research and research training through national competition across all disciplines.
	Time status	2001 - now
	Budget	
	Website	www.arc.gov.au
	Source	ARC NCGP
*	Name FA	**Forest and Wood Products Research and Development Corporation (FWPRDC) = Forest and Wood Products Australia (FWPA) (Melbourne, Victoria, Australia)**
	Name FP	
	Main goal	Forest and Wood Products Australia directs investment into research and development projects that are vital to the expansion and innovation of forest and wood product-based industries. This includes providing support for the development and promotion of sustainable practices. The results of our research and development programs are packaged to facilitate easy adoption by industry with a focus on sustainable growth and profitability.
	Time status	
	Budget	
	Website	www.fwprdc.org.au = www.fwpa.com.au
	Source	Haritos (2007); FWPA (2010); FWPA research
*	Name FA	**Grains Research and Development Corporation (GRDC) (Barton, ACT, Australia)**
	Name FP	
	Main goal	The Grains Research & Development Corporation is one of the world's leading grains research organisations, responsible for planning, investing and overseeing research and development, delivering improvements in production, sustainability and profitability across the Australian grains industry.
	Time status	Founded in 1990
	Budget	
	Website	www.grdc.com.au
	Source	Haritos (2007); GRDC R&D investment portfolio 2002-2009

* Name FA **Joint Venture Agroforestry Program (JVAP) (Canberra, NSW, Australia)**
Name FP
Main goal The Joint Venture Agroforestry Program (JVAP) was established in 1993 and is jointly funded by the Rural Industries Research and Development Corporation (RIRDC), Land & Water Australia and the Forest and Wood Products Research and Development Corporation, together with the Murray Darling Basin Commission, the Grains R&D Corporation, the Australian Greenhouse Office and the Natural Heritage Trust. The Program has been very active in the biobased products area.
JVAP assists the development of profitable agroforestry industries while delivering beneficial natural resource management outcomes. Agroforestry, or farm forestry, is about integrating trees and woody perennials into existing agriculture for multiple benefits, generally as mixed farming enterprises. Catchment managers can also use farm forestry to achieve re-vegetation targets.
Key long term strategies:

- Improved agroforestry designed to optimise social, economic and environmental factors at the paddock, farm and regional-landscape sale.
- New commercial products and value-added existing products, to promote profitable agroforestry industries.
- Improved product-market linkages through analysing product suitability, value and regional development options.
- Demonstrated mechanisms for valuation and trading of ecosystems services provided by agroforestry.
- New policy and institutional arrangements that stimulate agroforestry investment.

Time status 1993 - now
Budget
Website
Source Haritos (2007); RIRDC Agroforestry and farm forestry; JVAP projects and results

* Name FA **National Collaborative Research Infrastructure Strategy (NCRIS) (Canberra, NSW, Australia)**
The consortium partners include Macquarie University, University of Sydney, University of New South Wales, Queensland University of Technology & South Australian Research and Development Institute.
Name FP Australian Government. The managing agency is AusBiotech Ltd.
Main goal Through NCRIS, the Government provides researchers with major research facilities, supporting infrastructure and networks necessary for world-class research.
The goal is to enhance Australia's capacity to produce biotechnology products in pre-commercial quantities. Biofuels is a sub-project.
National Collaborative Research Infrastructure Strategy (NCRIS) funding has been committed to the establishment of research infrastructure for the development of novel biofuel production technologies. As part of the NCRIS project Recombinant Proteins and Biofuels project the following research infrastructure is being developed:

- a biomass biorefinery pilot plant in Queensland, located in Mackay and owned and operated by Queensland University of Technology, for the development and demonstration of the production of ethanol, lignin and other commodities from lignocellulosic biomass; and
- a photobioreactor facility in South Australia, located at the South Australian Research and Development Institute (SARDI), for pilot-scale development and demonstration of microalgal biomass culture for

		biodiesel production. This facility will be designed as a transportable laboratory that can be moved between pilot plant sites. Three universities provide support to researchers who have projects that are designed to produce improved technologies for the conversion of biomass to biofuels. Fermentation laboratories have been upgraded at the University of New South Wales and Macquarie University is expanding their enzymatic capabilities. A research-scale, high-pressure tube reactor is being built at the University of Sydney. A key principle of NCRIS is that the facilities funded by the programme should be accessible to researchers on the basis of merit at reasonable prices, wherever they are located in Australia.
	Time status	2007-2011
	Budget	$35 M for the Biotechnology Products sub-program, of which $16 M is allocated to the biofuels sub-project
	Website	ncris.innovation.gov.au; www.ncrisbiofuels.org
	Source	QUT (2009); NCRIS (2010a); NCRIS (2010b)
*	Name FA	**Rural Industries Research and Development Cooperation (RIRDC) (Kingston, ACT, Australia)**
	Name FP	
	Main goal	The Corporation was established by the Australian Government to work with industry to invest in research and development for a more profitable, sustainable and dynamic rural sector. The National and Rural Research Priorities of the Australian Government provide an over-arching framework for public investment in rural research and development. RIRDC's investments are closely aligned with these priorities.
	Time status	
	Budget	
	Website	www.rirdc.gov.au
	Source	RIRDC (2010)
*	Name FA	**Sugar Research and Development Corporation (SRDC) (Brisbane, Queensland, Australia)**
	Name FP	
	Main goal	The Sugar Research and Development Corporation works in partnership with the Australian sugarcane industry and the Australian Government to foster an innovative and sustainable sugarcane industry, through targeted investment in research and development. The Objectives of SRDC are directly related to the objects of the Primary Industries and Energy Research and Development Act. They are: • to improve the competitive position and cost efficiency of the Australian sugarcane industry; • to achieve sustainable use and sustainable management of the natural resource base of the sugarcane industry; • to apply industry, scientific and community resources more effectively to R&D in the sugarcane industry. SRDC invests in R&D activities to find new and improved ways of doing things rather than funding core services.
	Time status	
	Budget	
	Website	www.srdc.gov.au
	Source	Haritos (2007)

5.3 Research organisations Australia

*	Name	**Algal Fuels Consortium (AFC) (Adelaide, SA, Australia)** AFC comprises the South Australian Research & Development Institute (SARDI), Flinders University, the CSIRO Energy Transformed Flagship, Sancon Recycling Pty Ltd and Flinders Partners.
	Main goal	The AFC is developing a pilot-scale second generation biorefinery for sustainable production of microalgal biofuels and value added products. This collaborative research project will produce biomass from native strains of microalgae, from which biodiesel will be produced on a scale that is commercially viable. At the same time, the project will produce high value by-products including Omega-3 fatty acids, bioactive peptides and carotenoids used by the nutraceutical industry. The AFC will also develop low cost and efficient harvesting, dewatering, and oil extraction technologies and perform subsequent bioprocessing to produce high value co-products alongside biodiesel. The AFC will also undertake economic and life cycle analysis during this project in order to support a full commercial venture.
	Type BR	Marine biorefinery
	Time status	2009 - now
	Budget	2009 received a $2.724 M grant from Department of Resources, Energy and Tourism
	Website	
	Source	Flinders research grant

*	Name	**BSES Limited (Brisbane, Queensland, Australia)**
	Main goal	BSES Limited, an organisation owned exclusively by Australian sugarcane growers and millers. For more than a century, BSES has led research, development and extension services for Australian sugarcane production. BSES head office and major laboratories are located in Brisbane, Queensland. BSES has 17 other stations and centres serving major sugarcane growing districts between north Queensland and northern New South Wales. BSES is the principal provider of research, development and extension to the Australian sugarcane industry. The major topics are: • plant improvement; • crop management; • mechanisation enhancements; • product and process improvement; • analytical support; • customer service.
	Type BR	Whole crop biorefinery
	Time status	In August 2003, Legislation was passed by Queensland Parliament allowing the transfer of assets from the Bureau of Sugar Experiment Stations to BSES Limited.
	Budget	
	Website	www.bses.org.au
	Source	Haritos (2007)

* Name **Commonwealth Scientific & Industrial Research Organisation (CSIRO) (Clayton South, VIC, Australia)**

Main goal CSIRO is working on key-areas of the bioeconomy:

- pre-breeding in wheat, oilseeds, cotton and sugar;
- breeding in wheat, cotton, sugarcane and soybeans;
- bio-discovery and protein (enzyme) engineering;
- biobased materials development and processing.

CSIRO is divided in division. For biorefinery and biobased products the most relevant ones are:

- energy technology;
- food & nutritional sciences;
- land and water;
- livestock industries;
- molecular & health technologies;
- plant industries;
- sustainable ecosystems.

They are a member of the Algal Fuels Consortium™ with SARDI and Flinders University.

Type BR Oilseed biorefinery; Whole crop biorefinery

Time status

Budget

Website www.csiro.au

Source CSIRO (2008); Haritos (2007)

* Name **Cooperative Research Centre – for polymers (CRC Polymers) (Notting Hill, Victoria, Australia)**

Main goal The Cooperative Research Centre (CRC) for Polymers is a joint venture between its participants, incorporated through Polymers CRC Ltd, that was established and is supported under the Australian Government's Cooperative Research Centres Program. It is conducting agreed research, commercialisation, education and administration programs. These programs are carried out collaboratively between the participating companies, the participating universities and Government research laboratories in Australia.
The polymers for sustainable development program provides products based on polymer science and engineering that will assist in transforming the use of land, water and energy resources, so that they can be used on a more sustainable basis. The program consists of the following projects focusing on functional and degradable polymers:

- degradable packaging materials derived from renewable resources;
- degradable polyolefin films for agricultural production;
- functional polymers for photovoltaic devices;
- polymers for evaporation mitigation technologies.

Type BR

Time status Working over a seven-year period ending June 2012.
2005-2012

Budget

Website www.crcp.com.au

Source CRCP (2010)

*	Name	**Cooperative Research Centre – for Sugar Industry Innovation through Biotechnology (CRC SIIB) (St Lucia, Queensland, Australia)**
	Main goal	It is an alliance of Australia's top sugarcane biotechnology research organisations including four Universities, sugar industry research organisations, Federal and Queensland State Governments, and commercial expertise. Its Head Office is at The University of Queensland in Brisbane. The CRC's scientists and research scholars are based in Brisbane and in sugarcane towns throughout Queensland and northern New South Wales. Their new product development program will develop technologies and strategic alliances to deliver high-value biomaterials produced in sugarcane as alternative products or as co-products with sucrose, or produced by downstream processing of precursors harvested from sugarcane. Includes plastics, waxes, lignin products, fibres, enzymes. CRC-SIIB has a significant program of research and development to underpin sugarcane biorefining. Fermentation to ethanol and other renewable commodities and biomass treatment processes such as pulping are key technical elements of the biorefinery concept.
	Type BR	Whole crop biorefinery; Lignocellulosic feedstock biorefinery
	Time status	Established on 1 July 2003 under a seven-year joint research agreement. The CRC SIIB entered the commercialisation phase of its research in July 2006. 2003 - 2010
	Budget	
	Website	www.crcsugar.com
	Source	Haritos (2007); Edye et al. (2005)
*	Name	**Flinders University (Adelaide, SA, Australia) - BRENERGY Centre & Water Technologies Group**
	Main goal	Flinders University is working on the synergy of sustainable water, biofuels and biorefinery. They will develop a proof-of-concept facility of the Biorefinery model for algal biofuel (together with SARDI). They are a member of the Algal Fuels Consortium™ with SARDI and CSIRO. Flinders will be involved in production of the value-added products from the biomass. One example is development of methods to fractionate Omega-3 polyunsaturated fatty acids from the algal oil. Glycerol, which can be processed into high-value chemicals widely used in the production of paint and plastics, is another potentially profitable by-product.
	Type BR	Marine Biorefinery
	Time status	2009 - now
	Budget	$ 1.2 M
	Website	www.flinders.edu.au
	Source	Flinders (2008a); Flinders (2008b)
*	Name	**Macquarie University (Sydney, NSW, Australia)**
	Main goal	The fermentation laboratory has been upgraded through NCRIS funding. The NCRIS facility provides process development infrastructure for researchers seeking to develop and/or optimise processes for the production of enzymes for biomass degradation.
	Type BR	
	Time status	
	Budget	
	Website	www.mq.edu.au
	Source	NCRIS (2010c)

* Name **Murdoch University (Perth, Western Australia, Australia)**

Main goal The seagrass research group at Murdoch University carries out research on a wide range of basic and applied topics relating to phytoplankton, seaweeds and seagrasses. They range from the commercial production carotenoids by the large-scale culture of microalgae such as *Dunaliella salina* and *Haematococcus pluvialis* to algae for the production of lipids for biodiesel.
The BEAM network supports inderdisciplinary and collaborative research into understanding the limitations on microalgal growthsupporting the development of new, commercial-scale microalgae culture systems, the production of fine chemicals, bioactive compounds and renewable fuels (hydrogen and biodiesel), as well as environmental applications such as monitoring the physiological state of phytoplankton in the environment, management of algal blooms, CO_2 bioremediation and algal/bacterial systems for the bioremediation of contaminated soils. Research focuses especially on photosynthetic light utilisation efficiency and carbon fixation, chlorophyll fluorescence, biochemistry of secondary metabolites, molecular biology and photobioreactor design and engineering, informed by an understanding of the ecology of these algae.

Type BR Marine biorefinery

Time status

Budget

Website www.murdoch.edu.au

Source Algae group; BEAM

* Name **Qeensland University of Technology (QUT) – Centre for Tropical Crops and Biocommodities (CTBC) (Brisbane, Queensland, Australia)**

Main goal QUT-CTBC brings together a mix of international expertise in plant biotechnology, process engineering, industrial chemistry, and commercialisation. It was established in 2005 to bring together the Tropical Crop Biotechnology Program, and the Sugar Research and Innovation Program. It performs product research and development from gene discovery and genetic manipulation, through to field demonstration and pilot plant scale production specialising in tropical crops (including sugarcane, bananas, tobacco, papaya, tomato, taro and sorghum). The emphasis is on:

- the development of new crop cultivars through genetic modification for plant disease resistance and nutritional biofortification, and development of plant disease management technologies;
- the development of postharvest sugarcane processing technology, and treatment of crop biomass for producing new biomaterials including industrial and medical proteins, lignins and biofuels.

The Centre for Tropical Crops and Biocommodities has a broad range of expertise including crop biotechnology, industrial chemistry and process engineering.
In the research topic bioenergy CTCB:

- has a significant program of work in producing ethanol from second generation cellulosic feedstocks through biochemical processes;
- is developing transgene expression, transformation and processing technologies to express cellulase enzymes at high levels in sugarcane;
- is focussed on improvements in bioethanol pretreatment technologies using ionic liquids, alkalis, solvents and dilute acids;
- is undertaking work in thermochemical processing of biomass into biofuels;
- has considerable expertise in biomass combustion.

CTCB is also working on the development of new biopolymers, biomaterials and composites from biomass. Biomass fractionation using delignification/dissolution agents (e.g. tailor–made ionic liquids, conventional and non–conventional

pulping/thermal technologies) is being developed in the CTCB so that biomass components can be used in the manufacture of biofuels, thermosets and thermoplastics. Specifically, the researchers are involved in the development of short fibre composite technology, natural–based resins and paints, novel lignin polymers and bio–composites, biodegradable blown films and novel water–based coatings.
The SRI research program of CTCB focuses on the postharvest processing of sugarcane into sugar and other products. It includes enhancements to existing sugar production technologies and the development and investigation of new sugar production technologies. The research program is increasingly focused on a biorefinery approach to processing of the whole sugarcane plant for the production of additional high value biocommodities including biofuels.

Type BR	Lignocellulosic feedstock biorefinery
Time status	2005 - now
Budget	
Website	www.qut.edu.au; www.ctcb.qut.edu.au
Source	

* Name **South Australian Research and Development Institute (SARDI) (Adelaide & West Beach, SA, Australia)**

Main goal SARDI is developing a research capability in biofuels with an initial focus on biodiesel. SARDI Biofuels Research Program includes two subprograms - breeding and microalgae.
For the first subprogram 'Evaluation and development of new crops as feedstocks for biodiesel production' SARDI will use current breeding and farming systems capabilities to evaluate and develop canola and mustard varieties specifically tailored to biodiesel production. Some of these varieties will be targeted to cultivation in low-rainfall areas of the state, providing farmers with more crop choice in rotations. The objectives are:

- selection and breeding of varieties tailored to biodiesel production;
- development of agronomic packages to enhance adoption;
- economic and environmental evaluation of new varieties in farming systems.

At the moment the second subprogram 'Sustainable production of biodiesel from microalgae' is focused on micro-algal oil production but is also investigating crops, such as canola and mustard, for biodiesel production. The SARDI aquatic science research capability is selecting and developing microalgae as a source of oil for biodiesel. Both pond culture and bioreactors technologies are being researched at SARDI. The objectives are:

- bioprospecting native algae strains, laboratory culture and lipid profiling
- critical control studies to increase oil production
- evaluation of existing technologies
- development of labscale bioreactors and optimisation of algal oil production
- construction of demonstration scale bioreactors and evaluation of economic and environmental benefits.

They are a member of the Algal Fuels Consortium™ with Flinder University and CSIRO.

Type BR	Marine biorefinery
Time status	2004 - now
Budget	Breeding: A$1.1 million over three years Microalgae: A$1 million over three years
Website	www.sardi.sa.gov.au
Source	Government of South Australia (2010); SARDI (2010a); SARDI (2010b)

*	Name	**Sugar Research Institute (SRI) (Brisbane, Queensland, Australia)**
	Main goal	SRI was researching the biorefinery concept of complete utilisation of sugarcane biomass - a concept that is becoming a pivotal element for a sustainable sugarcane industry. The concept focuses on production of liquid fuels, electricity and commodity chemicals from a renewable source - sugarcane - that will produce financial benefits. Fermentation to ethanol and other renewable commodities and biomass treatment processes such as pulping are key technical elements of the biorefinery concept. SRI's capabilities in biorefining encompass: • knowledge of fractionation and reforming of input feedstocks into multiple product streams (such as to cellulosic and lignin components); • in-depth understanding the technologies required, including thermal processes such as hydrothermal liquefaction, chemical processes such as acid hydrolysis or solvent extraction, enzymatic processes such as cellulose hydrolysis, and microbial fermentation; • expertise in product streams, such as ethanol, biodiesel, hydrocarbon-like oils, agricultural chemicals, food ingredients, and bio-commodities; and • other value-adding opportunities such as furfural and bioplastics.
	Type BR	Lignocellulosic feedstock biorefinery; Whole crop biorefinery
	Time status	?? – 2005
	Budget	
	Website	www.sri.org.au
	Source	SRI (2005)

*	Name	**University of New South Wales (UNSW) – School of Biotechnology and Biomolecular Sciences (BABS) (Sydney, New South Wales, Australia)**
	Main goal	The School of Biotechnology and Biomolecular Sciences (BABS). The School aims to achieve a balance of pure basic, strategic basic, applied and experimental development research. Relevant research themes are: • environmental health and sustainability • microbial processes • biomaterials and nanotechnology • environmental genomics • biodiversity and conservation • bioprospecting for enzyme and drug discovery Using the latest enabling technologies in the biosciences, these areas of research excellence translate fundamental discovery science into practical societal and economic benefits in the areas of: • novel biocatalysts • novel bioactives • biofilm and biofouling control • water quality and water re-use • bioremediation and biofuels • monitoring and maintaining the health of Australian ecosystems Recent advances in systems biology and the newly developed biorefinery concept have led to a particular interest in Zymomonas mobilis as a platform organism. The fermentation laboratory has been upgraded through NCRIS funding. The new NCRIS facilities have been built on the existing fermentation and analytical equipment at UNSW and now provide an upgraded Fermentation Laboratory.
	Type BR	
	Time status	Formed in January 2002
	Budget	
	Website	www.unsw.edu.au; www.babs.unsw.edu.au
	Source	NCRIS (2010c); BABS (2010)

*	Name	**University of Queensland – Australian Institute for Bioengineering and Nanotechnology (AIBN) (Brisbane, Queensland, Australia)**
	Main goal	AIBN's capabilities come from merging the skills of engineers, chemists, biologists and computational scientists to conduct research programs e.g. on using metabolic engineering to produce new bioproducts from cells. A project focuses on the development of a novel commodity polymer from sugarcane. The main research aim is to improve production of polyhydroxyalkenoates (PHAs) in sugarcane, potentially providing a replacement for polyesters, the key ingredient in thermoplastic or elastomeric materials often used in packaging material.
	Type	BR
	Time status	
	Budget	
	Website	www.aibn.uq.edu.au
	Source	

*	Name	**University of Sydney (Sydney, NSW, Australia)**
	Main goal	A research-scale high-pressure tube reactor is being built through NCRIS funding. It will be the first semi-automated, continuous-flow pilot plant research facility in Australia to investigate the hydrothermal decomposition of biomass. The key differentiating factor of the facility will be the independent manipulation of temperature and pressure on a continuous flow basis. This will facilitate understanding the influence of residence time, biomass concentration and type, temperature and pressure, and their interactions, on the product composition under continuous flow conditions.
	Type	BR
	Time status	The facility is scheduled for commissioning in October 2009 and will be available for external users from April 2010.
	Budget	
	Website	www.usyd.edu.au
	Source	

5.4 Pilot plants Australia

*	Name	**QUT (Mackay, Queensland, Australia)**
	Name pilot	QUT Biomass biorefinery pilot plant/ Mackay renewable Biocommodities Pilot Plant
	Description	A biomass biorefinery pilot plant in Queensland for the development and demonstration of the production of ethanol, lignin and other commodities from lignocellulosic biomass. The facility is being hosted by Mackay Sugar Limited, one of Australia´s leading sugar manufacturers, on the site of at Racecourse Mill in Mackay and owned and operated by Queensland University of Technology. It is a publicly available research infrastructure to: • develop new biofuel technologies • demonstrate technologies that are close to commercialisation • scale up process to ensure economic viability • produce quantities of product for product testing.
	Feedstock	Cellulosic biomass; sugar cane bagasse & trash
	Products	Ethanol; lignin products; other fermentation products
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	Operational mid 2010
	Budget	$ unknown M; funded by the Australian Government through NCRIS Capability 5.5 – Biotechnology Products, the Queensland Government Department of Employment, Economic Development and Innovation and QUT
	Website	www.ctcb.qut.edu.au/programs/pilot.jsp
	Source	NCRIS (2010b); QUT (2009);

*	Name	**SARDI (Adelaide, South Australia, Australia)**
	Name pilot	SARDI microalgae photobioreactor facility
	Description	A photobioreactor facility in South Australia, located at the South Australian Research and Development Institute (SARDI) at its Aquatic Sciences Facility at West Beach, Adelaide. The demonstration scale facility will be located at Torrens Island. It is intended for pilot-scale development and demonstration of microalgal biomass culture for biodiesel production. This facility will be designed as a transportable laboratory that can be moved between pilot plant sites. It provides the capability to research microalgal growth in experimental photobioreactors and raceways as well as develop algal production systems in one central location.
	Feedstock	
	Products	biodiesel
	Type BR	Marine biorefinery;
	Time status	The West Beach facility is available for access now. Construction and commissioning of the Torrens Island demonstration scale algal cultural systems will be completed and the facility will be available for use mid 2010.
	Budget	$ 5 M; NCRIS funding
	Website	
	Source	NCRIS (2010b); NCRIS (2010c); SARDI (2009)

6 Asia

6.1 Introduction Asia

6.1.1 China

The development of biorefineries in China is driven mainly by the energy demand of an expanding manufacturing sector and the effect of the increasing costs of fossil fuels. Renewable energy made up 7% of the energy mix in China in 2007, and target is a 16% renewable energy use by 2020. Biofuels are expected to meet 15% of China's transportation energy needs by 2020. Next to biomass, renewable energy also includes hydro, wind and solar power. China has 7% of the world's cultivated land, yet must feed 20% of the world's population. Further, the 120 million ha of arable land is shrinking due to desertification and sand encroachment, while half of the land in China is marginal. China's Energy Research Institute in Beijing is therefore focusing upon mapping the marginal areas of land for suitability for growing different crops for biorefineries (Knights, 2007; EPOBIO workshop, 2007, Biorefinery Euroview, 2008).

The policy of the government of China is that "biofuels will meet 15% of China's transportation energy needs by 2020" (Kao, 2007). This means 12 million tonnes of bioethanol by 2020 (Biorefinery Euroview, 2008). The policy of the government of China is to restrict grain processing into fuel ethanol since food prices increased in 2007. The government's policies have turned to support non-grain based fuel ethanol production: cassava, sweet potato, and sweet sorghum. However, current domestic production is not able to sustain large ethanol production (Beckman, 2009; Biorefinery Euroview, 2008). China aims to use part of its 116 million ha of marginal land for the production of cassava, sugar cane, shrubs and other biofuel feedstocks (Lou Schwartz, 2007). Furthermore, it is predicted that 30% of the 720 million tonnes of corn straw residue available could be used for bioethanol production (Biorefinery Euroview, 2008).

Economic incentives are more developed for bioethanol than for biodiesel (Kao, 2007). Biodiesel production just began to be addressed in 2006, while diesel consumption in China is about twice that of gasoline (Biorefinery Euroview, 2008). The State Administration of Taxation and Ministry of Finance jointly issued policies which stipulated that a VAT refund would be applicable to enterprises that produce biodiesel by making use of wasted animal oil or plant oil for at least 70 percent of their raw materials. However, industry sources report that this policy is not very well implemented at the provincial level due to different interpretations by local taxation authorities (Beckman, 2009). Potential feedstock for biodiesel production currently being investigated include: Jatropha, Chinese pistachio and yellow horn (Knights, 2007; EPOBIO workshop, 2007; Biorefinery Euroview, 2008).

Projects to develop bio-butanol and to use the by-products of isoprenol and protein and to re-use carbon dioxide emissions are in development. The production of methanol from coal and di-methyl ether is also being developed. One of the top priorities of the science and technology innovation in China is clean energy and environmental protection (Knights, 2007; EPOBIO workshop, 2007).

An overview of information related to renewable energy in China is provided at www.martinot.info/china.htm.

Figure 5 Map of China (source: http://www.paulnoll.com/China/Provinces/I-China-map.gif)

6.1.2 India

India's Biofuel drivers are (Singh, 2009):

- The cornerstone of India's energy security strategy is to focus efforts toward energy self-reliance and developing renewable energy options like biofuels vis-à-vis fossil fuels.
- The policy aims the adoption of environmentally friendly biofuels to meet improved vehicle emission norms.
- Developing an alternative usage for crops like sugarcane and its by-products as feedstock for biofuels to support farm income. Currently, bioethanol is being produced from molasses, a by-product of India's large sugar industry. Due to the cyclic nature of sugar production, farmers experience fluctuating income. Bioethanol outlet for sugarcane could help stabilizing farmers income. However, the cyclic nature of sugarcane and sugar production and related molasses prices will cause fluctuating bioethanol prices, which will affect the ethanol blended petrol (EBP) program.
- Improve utilization of wastelands and other unproductive land for cultivation of biofuel feed stock. Biodiesel production efforts are focused on using non-edible oils, animal fats, and waste oil. Focus is to use wastelands for cultivation of new biofuel crops like *Jatropha curcas*, *Pongamia pinnata* and other tree borne oilseeds. This in order to avoid competition with food crops on scarce agricultural land. Plantations are young however, 60-70 % are less than 3 years old and not yet in full production. At

the same time, Jatropha can grow on marginal soil, however, the seed yield seems proportional to availability of water.

- Enhance rural employment and livelihood opportunities by promoting production and marketing of biofuel feed stocks. Cultivation of non-edible oil crops on wastelands aims to provide additional employment to the vast rural population in India.

As India does not produce any ethanol from cereal grains, there is no impact of the ethanol program on the domestic market for food, feed and trade of cereal grains (Singh, 2009). Biomass-based fuels support over 80 % of home energy use in India already, mostly for cooking and heating. This biomass consists of agricultural by-products such as crop residues, cow dung, and gathered wood. Total biomass energy accounts for almost one-third of India's total primary energy consumption needs (Singh, 2009).

Figure 6 Map of India (source: http://www.mapsofindia.com/maps/india/india-political-map.htm).

6.1.3 Japan

Government and private sector research and investment in biofuels have been on the rise since Japan's first biomass plan "Biomass Nippon Strategy" was unveiled in December 2002. This Strategy was updated in 2008, and the Government of Japan's (GOJ's) current thinking, given limited agricultural resources, is to focus very determinedly on cellulosic biofuel as the future for Japan's biofuel production (Iijima, 2009). Strange enough, the Biofuels status report by Iijima does not mention biofuels from marine source, whereas the Fisheries Research Agency of Japan has funded a large consortium including Tokyo University, Mitsubish Research Inc. and several other companies to develop a bioethanol production plant using a 10,000 square km seaweed farm in the Sea of Japan (Blogonsmog, 2009) (also see section 6.2.3).

Japan's greenhouse gas emissions in fiscal year 2007 increased by 8.7% from the 1990 level. This has put the GOJ under pressure to turn that around in order to meet Kyoto Protocol commitments. With it's limited agricultural production, it will be very difficult for Japan to produce enough biofuels to impact the domestic fuel market and thereby greenhouse gas emissions without a major technological breakthrough, e.g. cellulosic technology (Iijima, 2009).

Several ministries collaborate on Japan's biofuels policy. Substantial discussions and coordination among the ministries are done in the Executive Committee on Biomass Nippon Strategy. The Ministry of Environment's (MOE) main concern is meeting Kyoto Protocol commitments, preventing global warming, and expanding the conversion of waste products into energy. The Ministry of Economy, Trade and Industry (METI) collaborates with industry and is interested in analyzing the cost-benefit of shifting to renewable fuels and their impact on automobiles and infrastructure and, as a consequence, is heavily involved in feasibility studies. While the Ministry of Agriculture Forestry and Fisheries (MAFF) is interested in utilizing existing biomass (sugarcane, woody materials, rice, and rice straws and husks, etc.) in the production of energy, and its focus has shifted toward cellulosic methods and away from increasing production of biomass. MAFF estimates that by 2030 6 billion litres of biofuels per year may be produced in Japan, an aim which is not shared by all Ministries (Iijima, 2009).

There is more diversity between Ministries visions and approaches. MOE promotes direct blending while METI supports the ETBE method. The reason for the latter is that it is more costly for oil distributors to renovate the facilities for direct blending. MAFF has favoured promoting direct blending. However, it is yielding to support the ETBE method in order to secure the distribution channel for domestically produced bioethanol (Iijima, 2009).

The GOJ introduced tax incentives to encourage the use of bioethanol. The legislation includes tax breaks and financial assistance for biofuel manufacturers and farmers producing feedstock, such as agricultural cooperatives and private businesses. Fixed property tax for newly built biofuel facilities will be reduced in half for three years. Interest-free loans for a redemption period of ten years will be provided to farmers producing feedstock (Iijima, 2009).

During the past few years, as food prices have increased and food insecurity in Japan and around the world captured headlines, biofuels have been under increasing criticism by Japanese lawmakers and media, often bearing the blame for those higher prices. On the other hand, even when making bioethanol from food commodities like rice or wheat, only a fraction of current food market would be required, according to claims (Iijima, 2009).

Figure 7 Map of Japan (source: http://ease.com/~randyj/japanmap.htm).

6.2 Funding programmes Asia

6.2.1 China

*	Name FA	**Energy Foundation China**
	Name FP	The China Sustainable Energy Program (CSEP)
	Name FA	Energy Foundation China
	Main goal	The programs strive to build institutional capacity in China to analyze energy-saving and renewable-energy opportunities. CSEP helps Chinese agencies, experts, and entrepreneurs solve energy challenges for themselves.
	Time status	Started in 1999
	Budget	Over US$ 60 million since start
	Website	www.efchina.org
	Source	Programs of EF China

*	Name FA	**Ministry of Science and Technology of China**
	Name FP	• National High-tech R&D Program (863 Program) • National Basic Research Program of China (973 Program)
	Main goal	• 863: a.o. enhance the overall bio-technological R&D level and capacity. • 973: mobilize China's scientific talents in conducting innovative research on scientific issues areas like a.o. energy, resources and environment, and materials
	Time status	• 863: Started in 1986, run to at least 2006. • 973: Started in 1997, run to at least 2006.
	Budget	
	Website	www.most.gov.cn
	Source	863 Program; 973 Program

*	Name FA	**National Development Reform Commission (NDRC)**
	Name FP	Many, one of which is: Program of Action for Sustainable Development
	Main goal	One of the central goals of the NDRC is to promote the strategy of sustainable development; to undertake comprehensive coordination of energy saving and emission reduction; to organize the formulation and coordinate the implementation of plans and policy measures for recycling economy, national energy and resource conservation and comprehensive utilization; to coordinate the solution of major issues concerning ecological building, energy and resource conservation and comprehensive utilization; to coordinate relevant work concerning environment-friendly industries and clean production promotion. The Department of Resource Conservation and Environmental Protection is, a.o. responsible for organizing and coordinating key pilot programs of energy conservation and emission reduction, and promotion and application of new products, technologies and equipments. During the 11th Five-Year Program period, the NDRC will further strengthen the guidance through programs and policy and will encourage independent innovation of enterprises so as to promote the coordinated development of science, technology and economy. The NDRC establishes enterprise technology centers, builds national science and technology infrastructures, sets up national engineering research centers and laboratories, organize research and manufacturing programs, organize industrial technology development programs in a.o. clean and efficient energy.

		The Program of Action for Sustainable Development, focuses a.o. on the development of renewable energy and the use of marine resources.
	Time status	The above relates to the 11th 5 year plan.
	Budget	
	Website	en.ndrc.gov.cn
	Source	Program of Action for Sustainable Development; NDRC functions; Department of Resources Conservation and Environmental Protection; NDRC tasks

*	Name FA	**National Natural Science Foundation of China**
	Name FP	Wide range of programs, including Life Sciences
	Main goal	NSFC directs, coordinates and financially supports basic research and applied basic research, identifies and fosters scientific talents, promotes science and technology, and pushes ahead economic and social development in China.
	Time status	In operation
	Budget	Yuan 5.36 billion in 2008, equal to € 570 million
	Website	www.nsfc.gov.cn
	Source	Departments and Offices; Main Responsibilities; Funding in 2008

6.2.2 India

Programs are not always specifically focused on biorefinery, but do cover biorefinery issues.

*	Name FA	**Council of Scientific and Industrial Research (CSIR)**
	Name FP	New Millennium Indian Technology Leadership Initiative (NMITLI)
	Main goal	Seeks to build, capture and retain for India a leadership position in technology by synergizing the best competencies of publicly funded R&D institutions, academia and industry. Areas include agriculture & plant biotechnology, general biotechnology, bioinformatics, chemicals, materials and energy, but also areas like healthcare, information technology. NMITLI is a public-private-partnership effort within the R&D domain. CSIR combines a total of 38 laboratories.
	Time status	Since 2001
	Budget	So far INR 500 crore, equal to about € 75 million. € 110 million made available by Cabinet Committee on Economic Affairs in 11th 5-year plan, announced February 23rd, 2009.
	Website	www.csir.res.in
	Source	NMITLI info; NMITLI info 2; NMITLI expansion

*	Name FA	**Ministry of New and Renewable Energy (MNRE)** (formerly Ministry of Non-Conventional Energy Sources, MNES)
	Name FP	Many programs
	Main goal	The areas covered include: Biomass Power, Biomass Gasification, Anaerobic digestion for production of biogas/syngas, Pyrolysis, Biorefinery concepts, Biofuels from lignocellulosic feedstock, Biodiesel from all kinds of feedstock, Bio-Catalysis.
	Time status	Since 1999
	Budget	INR 10,460 crore budgeted for all programs in period 2007-2012, equal to € 1,600 million
	Website	http://mnes.nic.in
	Source	http://mnes.nic.in (sub Research Design and Technology Development – Bio-Energy & sub Annual/Five year plans – Plan summary)

*	Name FA	**Ministry of Science and Technology – Department of Biotechnology (DBT)**
	Name FP	Biofuel and Bioenergy program
	Main goal	• economically viable production of ethanol using different raw material and efficient, high yielding strains of microorganisms • biodiesel production for oil(s) and hydrocarbon using alternate feed stock especially lignocellulosics wastes and improved transesterification process • production of hydrogen from algae and bacteria.
	Time status	
	Budget	
	Website	http://dbtindia.nic.in
	Source	Biofuel and Bioenergy program;

*	Name FA	**Ministry of Science and Technology – Department of Science and Technology (DST)**
	Name FP	Technology Systems Development Programme (TSDP)
	Main goal	Developing and integrating technologies to evolve technology systems both in the advanced/emerging areas and in traditional sectors/areas. The areas covered include: Energy Generation and Harvesting, Alternative Fuels (Biofuels), and Fuel Conservation.
	Time status	Since 2004 (at least)
	Budget	On average INR 2,500,000/project of 3 year duration, equal to about € 38,500
	Website	http://dst.gov.in
	Source	DST technology systems development program

*	Name FA	**Technology Information, Forecasting and Assessment Council (TIFAC), Department of Science and Technology**
	Name FP	Bioprocess & Bioproducts Programme
	Main goal	Address critical technology needs for, a.o.: enzymatic processes towards development of active pharmaceutical ingredients, neutraceuticals, phyto-chemicals, value-added bio-products, bio-energy & biofuels.
	Time status	Since 2007
	Budget	
	Website	www.tifac.org.in
	Source	TIFAC Bioprocess and products program

In India, individual states also have their own funding programs which cover biorefinery R&D (see Appendix C).

6.2.3 Japan

In Japan, programs are rather organized per type of cooperation, and not particularly focusing on technical content.

*	Name FA	**Fisheries Research Agency**
	Name FP	No specific program name found
	Main goal	Developing technology for utilizing marine biomass as a new energy resource
	Time status	
	Budget	
	Website	www.fra.affrc.go.jp
	Source	JFS, 2008

* Name FA **Japan Science and Technology Agency (JST)**

Name FP Several
(Programs are rather organized per type of cooperation, and not particularly focusing on technical content)

Main goal JST focuses on several levels of science and technology development:

- Basic Research Programs: Creation of scientific and technological 'seeds' to stimulate future innovation in science and technology and create new technologies.
- Collaborative Development of Innovative Seeds: aims to verify the potential and practical implementation of basic research seeds, found out through industry's viewpoint.
- Science and Technology Research Partnership for Sustainable Development (SATREPS): Promoting joint research between Japan and developing countries, covering research contributing to: adaptation to or mitigation of climate change; energy systems for low carbon society; solution of global-scale environmental issues; sustainable utilization of bioresources.

Time status Ongoing

Budget

- Basic Research Program: 114 billion yen in 2008, equal to about € 95 million. Subdivided into several programs like CREST (40 – 120 million yen/year per project team) and ERATO (40 – 200 million yen/year per project team).
- Collaborative Development: up to 58 million yen per 4-year project, equal to € 500,000 (maximum of 50% of total project budget)
- SATREPS: up to US $ 400,000/year per project in fiscal year 2010.

Website www.jst.go.jp

Source JST Basic Research Programs; JST Basic Research Program; JST Collaborative Development; JST SATREPS Guideline;

* Name FA **Japan Society for the Promotion of Science (JSPS)**

Name FP Research for the Future Program
(Biorefinery may also fit in several other JSPS programs as well. There are several broadly defined programs for international and bilateral cooperation and for individual researchers. It looks like JSPS programs are rather organized per type of cooperation, and not particularly focusing on technical content.)

Main goal JSPS's main functions are:

- To foster young researchers,
- To promote international scientific cooperation,
- To award Grants-in-Aid for Scientific Research,
- To support scientific cooperation between the academic community and industry, and
- To collect and distribute information on scientific research activities.

Research for the Future Program:

- Development of next-generation process technologies for enhancing raw material industries while mitigating their environmental impact (including chemical reactions affected under supercritical conditions and industrial-scale applications of low-temperature plasma chemical reactions).
- Establishing novel principles and technologies for energy generation and conversion in the future, and achieving a breakthrough in fundamental problems that impede practical applications. Principal subjects addressed include renewable energy; conversion between electrical, chemical, solar and thermal energies; and advanced materials and systems.

Time status 1996-2002 indicated for Research of the Future Program

	Budget	Overall JSPS funding in 2007 was 222 billion yen, equal to € 1.8 billion.
	Website	www.jsps.go.jp
	Source	JSPS general functions; JSPS Research for Future Program; JSPS Next-generation Process Technologies; JSPS Innovation in Energy Generations;
*	Name FA	**New Energy and Industrial Technology Development Organization (NEDO)**
	Name FP	Accelerated Technology Development for Biofuels
	Main goal	NEDO's mission is: 1) Address energy and global environmental problems, 2) Enhance Japan's industrial competitiveness. NEDO actively undertakes the development of new energy and energy-conservation technologies, verification of technical results, and introduction/dissemination of new technologies (e.g., support for introduction). This program includes common basic technology development to support the biofuel manufacturing process, as well as R&D of a biorefinery such as biopropylene. Themes are: Efficient production of cellulosic ethanol; Bioethanol production by mechanochemical pulping; Bioethanol production process from woody biomass based on high efficient solvolysis and ethanologenic bacteria; Membrane separation process technologies; Saccharification of cellulosic resources; Technologies to produce propylene from cellulosic ethanol.
	Time status	Running
	Budget	10s-100s million yen/theme, equal to € 100,000s – 1,000,000s/theme
	Website	www.nedo.go.jp
	Source	NEDO Joint Research Program, 2006

6.3 Research organisations Asia

6.3.1 China

*	Name	**Beijing Forestry University – College of Material Science and Technology (BFU) (Beijing, China)**
	Main goal	Isolation and modification of cellulose and hemicellulose from biomass • Isolation of cellulose from sugarcane bagasse using ultrasound • Use of hemicellulose in papermaking • Etherification of hemicelluloses from sugarcane bagasse • Rapid esterification of wheat straw hemicelluloses induced by microwave irradiation
	Type BR	Lignocellulosic feedstock biorefinery / biochemical pathway
	Time status	
	Budget	
	Website	www.bjfu.edu.cn
	Source	Int Conf on Biorefinery, 2007; Liu, 2006; Ren, 2006; Ren, 2007; Xu, 2008

*	Name	**Beijing Institute of Technology (BIT) – School of Life Science and Technology (Beijing, China)**
	Main goal	Fast conversion of glycerol into 1,3-propanediol
	Type BR	Oilseed biorefinery
	Time status	
	Budget	
	Website	english.bit.edu.cn
	Source	Zhang, 2007b

*	Name	**Beijing University of Chemical Technology – College of life science and technology (BUCT-CLST) (Beijing, China)**
	Main goal	Production of base chemicals, fuel and biomaterials from lignocellulose biomass, including: • Immobilized lipase for production of biodiesel, on a cotton fabric membrane or on PVA/chitosan • Starch waste water fermentation into biodiesel, using *Rhodotorula glutinis* • Fuel ethanol from cassava • Fuel ethanol from cellulose (pilot) • Microbial production of 1,3-propanediol from waste glycerol from biodiesel production
	Type BR	Lignocellulosic feedstock / biochemical pathway
	Time status	
	Budget	
	Website	www.buct.edu.cn
	Source	Tan, 2002; Tan, 2006; Wang, 2007; Tianwei Tan, 2009

*	Name	**Central South University (CSU) – School of Chemistry and Chemical Engineering (Changsha, Hunan, China)**
	Main goal	Pretreatment of lignocellulose
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.csu.edu.cn
	Source	Zhao, 2007

*	Name	**China Agricultural University (CAU) – College of Water Conservancy and Civil Engineering (Haidian, Beijing, China)**
	Main goal	Biomass (corn stalks) flash pyrolysis technology using plasma for bio-oil production.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.cau.edu.cn
	Source	www.cau.edu.cn/water; Xiu, 2005

*	Name	**Chinese Academy of Agricultural Science – Oil Crops Research Institute (OCRI) (Wuhan, Hubei, China)**
	Main goal	• Nano-immobilized enzyme for conversion of rapeseed 'meal' into products • Development of lipase • Key activities of OCRI are plant genetics, breeding and cultivation
	Type BR	Lignocellulosic feedstock biorefinery / biochemical pathway
	Time status	
	Budget	
	Website	www.oilcrops.com.cn/english
	Source	Dong Xu-Yan, 2008; OCRI Processing; Zhang, 2007; Hu, 2007

*	Name	**Chinese Academy of Sciences – Dalian Institute of Chemical Physics (DICP) (DaLian, LiaoNing, China)**
	Main goal	• Hydrogen storage materials • Direct conversion of methane into aromatics and hydrogen • Direct Catalytic Conversion of Cellulose into Ethylene Glycol Using Nickel-Promoted Tungsten Carbide Catalysts • Direct methanolysis of oleaginous microbial biomass into biodiesel • Lipids fermentation • Microalgae for energy
	Type BR	Oilseed biorefinery; Marine biorefinery (microalgae); Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.english.dicp.ac.cn
	Source	DICP Research Highlights; DICP Recruitment; DICP Biomass conversion; Liu, 2007

*	Name	**Chinese Academy of Sciences – Guangzhou Institute of Energy Conversion (GIEC) (Wushan, Guangzhou, China)**
	Main goal	Research fields including renewable energy based on biomass and solid waste energy, more particular: biomass bio-chemical conversion technologies, biomass thermal-chemical conversion technologies, biomass-based chemical production technologies, waste treatment and utilization technologies. The researches focus on biodiesel, fuel ethanol, biomass pyrolysis and gasification, biomass gasification and power generation, synthesized fuels, bio-oil up-grading, MSW comprehensive utilization etc.
	Type BR	Oilseed biorefinery; Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	english.giec.cas.cn
	Source	Biomass Energy Research Center; Zhang, 2006

*	Name	**Chinese Academy of Sciences – Institute of Microbiology (IMCAS) (Beijing, China)**
	Main goal	The department's main research areas include: • Research and development in new important biomass products; • Development and application of new biocatalysts; • Development and application of gene manipulation techniques in microorganisms of industrial importance
	Type BR	Lignocellulosic feedstock biorefinery / biochemical pathway
	Time status	
	Budget	
	Website	www.im.ac.cn
	Source	Institute of Microbiology - Research

*	Name	**Chinese Academy of Sciences – Institute of Process Engineering (IPE) (Shanghai, China)**
	Main goal	Key Laboratory of Green Process and Engineering: • Investigate and develop new theories, new processes, innovative technologies, and industrialized technical integration with high efficiency and clean attributes for upgrading process in environmental and ecological industry systems and materials industries. Biomass Engineering Research Center (BERC): • Researches on the structural features of biomass component and new process and new methods for biomass components separation; • Key technologies for bio-based liquid fuels refining (fuel ethanol, butanol, biodiesel, bio-oil) • Key technologies for Bio-gas refining (methane, hydrogen, gasification) • Key technologies for biomaterials and biochemicals refining (Succinic acid, 1,3 - propanediol, PHB, high-purity lignin, furfural, xylose, xylitol)
	Type BR	Lignocellulosic feedstock biorefinery / biochemical pathway
	Time status	
	Budget	
	Website	http://english.ipe.cas.cn
	Source	IPE-CAS Green Process; IPE-CAS BERC; Li, 2010

*	Name	**Chinese Academy of Sciences – Shanghai Institutes for Biological Sciences Microbiology (SIBS) (Shanghai, China)**
	Main goal	Developing genetically-based bioproducts and bioprocesses by: • metabolic engineering of industrial microorganisms such as *Clostridia, Escherichia coli, Bacillus subtilis* and yeast; • protein engineering of industrial enzymes; • development and application of new technologies for engineering genes, proteins, pathways and genomes.
	Type BR	Lignocellulosic feedstock biorefinery / biochemical pathway
	Time status	
	Budget	
	Website	http://english.sibs.cas.cn
	Source	SIBS, 2009

*	Name	**Chinese Academy of Sciences – Tianjin Institute of Industrial Biotechnology (TIB.CAS) (XiQiDaoTianjin, China)**
	Main goal	Activities include: • Protein science and bio-catalysis engineering: textile, food, pharmaceutical • Bio-synthesis and microbial manufacturing engineering: plastics, adhesives, solvents • Biological systems and bio-process engineering
	Type BR	Biochemical pathway
	Time status	
	Budget	
	Website	http://english.tib.cas.cn
	Source	TIB Research areas

*	Name	**Chinese Academy of Sciences – University of Science and Technology of China – Anhui Province Key Laboratory of Biomass Clean Energy (Hefei, Anhui, China)**
	Main goal	Hydrocracking of pyrolytic lignin to liquid fuel in supercritical ethanol
	Type BR	Lignocellulosic feedstock biorefinery / thermochemical pathway
	Time status	
	Budget	
	Website	en.ustc.edu.cn/Laboratories
	Source	Tang, 2010

*	Name	**China Biomass Development Center (Beijing, China)**
	Main goal	Thermal pyrolysis, including gasification, liquefaction and carbonization, for treating crop and/or forest residues, industry organic wastes to produce fuel gas, biodiesel and coke fuel.
	Type BR	Lignocellulosic feedstock biorefinery / thermochemical pathway / syngas platform biorefinery
	Time status	
	Budget	
	Website	
	Source	BiorefInteg, 2009-p39; BiorefInteg, 2009-p55; Yuan Zhenhong, 2001; Yuan Zhenhong, 2004; Fan Feng, 2008

*	Name	**Dalian University of Technology – Institute of Coal Chemical Engineering, School of Environmental and Biological Science and Technology, Department of Bioscience and Biotechnology (DaLian, LiaoNing, China)**
	Main goal	Activities include development of: • Catalytic pyrolysis of agricultural biomass (legume, durra, rice, and corn stalks) • 1,3-propanediol production from glycerol from biodiesel production • 2,3-butatendiol production from Jerusalem artichoke tuber
	Type BR	
	Time status	
	Budget	
	Website	www.dlut.edu.cn
	Source	Song, 2003; Mu, 2006; Sun, 2009

* Name **East China University of Science and Technology – State Key Laboratory of Bioreactor Engineering (ECUST-SKLBE) (Shanghai, China)**
Main goal Activities include:
- Development of succinic acid production
- Hydrolysis and fermentation of lignocellulosic biomass, including attention for inhibition products

Type BR Lignocellulosic feedstock biorefinery / Biochemical pathway
Time status
Budget
Website www.ecust.edu.cn
Source Wu, 2007; ECUST-SKLBE; Jing, 2009; Niu, 2009; Lu, 2010

* Name **Energy Research Institute of National Development and Reform Commission (Beijing, China)**
Main goal Biomass energy technology
Type BR
Time status
Budget
Website www.eri.org.cn
Source ERI Renewable Energy

* Name **Fujian Academy of Agricultural Sciences (FAAS) (Fuzhou, Fujian, China)**
Main goal Generating bio-energy from manure
Type BR Other
Time status Proposal
Budget
Website www.faas.cn
Source Wageningen UR internal status report

* Name **Hebei New Bio-Energy Engineering & Technology Research Center (Qinhuangdao, Hebei, China)** (affiliated to Qinhuangdao Leading Science & Technology Development Co., Ltd)
Main goal Main research areas are:
- Research and development of synergistic bio-preparation of fertilizer, including poly glutamic acid, poly aspartic acid, humic acid, etc
- Research and development of new energy, including producing biodiesel, bio-hydrogen, and bioethanol by making use of discarded biomass materials and straws

Type BR Lignocellulosic feedstock / biochemical pathway
Time status
Budget
Website www.leadst.cn
Source Leadst Research Center

* Name **Henan Agricultural University (HAU) – Key Laboratory of Renewable Energy (Zhengzhou, Henan, China)**
Main goal
- Biodiesel from Tung oil
- Biodiesel from tallow

Type BR Oilseed biorefinery
Time status
Budget
Website www.henau.edu.cn
Source Xu, 2006c; TCSAE item 49

*	Name	**Hunan Agricultural University (HUNAU) – College of Science (Changsha, Hunan, China)**
	Main goal	Pretreatment of lignocellulose
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.hunau.net
	Source	HUNAU College of Science; Zhao, 2007

*	Name	**Jiangnan University – School of Biotechnology** (formerly known as Southern Yangtze University) **(Wuxi, Jiangsu, China)**
	Main goal	Research directions: • key & universal technologies in modern fermentation engineering and high technology for traditional fermentative industries promotion; • microbial metabolism regulating and modern breeding technologies; • biological technologies in pollutants treatment & control as well as synthesis of biomaterials friendly to environment; • microbiological pharmacology, chemistry of natural products; • biocatalysts, biochemical reaction, bio-energy techniques, and fine biochemistry. • Esterification of waste frying oil into biodiesel
	Type BR	Oilseed biorefinery
	Time status	
	Budget	
	Website	www.jiangnan.edu.cn
	Source	School of Biotechnology ; Zhang, 2008c

*	Name	**Liaoning Technical University (LNTU) (Fuxin, Liaoning, China)**
	Main goal	Pyrolysis of biomass (corn stalks)
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.lntu.edu.cn (In Chinese language)
	Source	Zhou, 2005

*	Name	**National Taiwan University of Science and Technology – Department of Chemical Engineering (Taipei, Taiwan, China)**
	Main goal	Main research areas are: • Production of biodiesel from rice bran oil, using acid-catalyst and lipase-catalyst • Isolation and purification of gamma-oryzanol (compound used in food supplements for several conditions including: menopausal symptoms, mild anxiety, stomach upset, and high cholesterol) from crude rice bran oil by solvent crystallization • Isolation and purification of squalene (compound used in cosmetics as natural moisturizer and in biosynthesis of cholesterol) from soybean oil deodorizer distillate
	Type BR	Oilseed biorefinery
	Time status	
	Budget	
	Website	www-e.ntust.edu.tw
	Source	Chemical Engineering; Zullaikah, 2005; Lai, 2005; Gunawan, 2008; Zullaikah, 2009

* Name **Northeast Normal University (NENU) – School of Chemistry (Changchun, Jilin, China)**
Main goal Synthesis of diphenolic acid from levulinic acid, using mesoporous silica catalysts
Type BR
Time status
Budget
Website en.nenu.edu.cn
Source Guo, 2007

* Name **Qinghua University – Department of Chemical Engineering (Beijing, China)**
Main goal Biodiesel production from waste oil in supercritical conditions
Type BR Oilseed biorefinery
Time status
Budget
Website No website found
Source Sun, 2006

* Name **Shandong University (SDU) – State Key Laboratory of Microbial Technology (SKLMT) (Jinan, Shandong, China)**
Main goal At present, the research activities in this Laboratory include 5 fields:

- Novel technologies for microbial conversion of biomass, such as lignocellulosics biodegradation, the isolation and genetic improvement of microorganisms which can actively degrade lignin and cellulose, the modification, production and application of cellulases and other related enzymes, the microbial conversion of agricultural and industrial wastes into useful products, and the production of feed additives and hydrogen using photosynthetic bacteria.
- Microbiology studies on resource exploration and environmental improvement, such as oil recovery by microorganisms or their fermentation products, bacterial leaching, microbial treatment of environmental pollutants, the development of the clean processes like bacterial desulfurization, biopulping and biobleaching, the production of environment friendly products, e.g. biodegradable plastics, bioinsecticide and biofertilizers, and the exploitation of marine microbial resources and microbial transformation of marine resources.
- Development of new fermentation technology and products, such as search for new pharmaceuticals (glutamine, L-carnitine and flammulin), food and feed additives (nisin, probiotics and photosynthetic bacteria), enzyme preparation (lipase, pectinase, pullulanase and so on), functional food, physiologically active substances, biocides or biostatics and biopolymers.
- Research on molecular biotechnology, such as genetic improvement and modification of microorganisms used in fermentation industries by gene manipulation, protein engineering, and metabolic engineering so that they can be efficiently applied to a large-scale production. Right now, the main topics are focused on the construction of autotrophic *Thiobacillus* with high arsenic tolerance, the improvement of industrial strains of *Saccharomyces cerevisiae* with killer activity, the genetic construction of high expression systems for gene transfer in filamentous fungi, and the property modification of industrial enzymes by the directed evolution.
- Optimization and control of biochemical and fermentation processes, such as quantitative physiology, distribution analysis of metabolic flux, kinetics modelling of bioprocess, computer control and optimization of fermentation and new fermentation technologies (fed-batch cultivation,

continuous cultivation, immobilized cell cultivation, high cell density cultivation and fermentation coupled with separation), as well as the design of new bioreactors and the isolation of fermentation products.

Type BR	Lignocellulosic feedstock biorefinery
Time status	
Budget	
Website	www.sdu.edu.cn; State Key Laboratory of Microbial Technology
Source	SKLMT Intro;

* Name **Shandong University of Technology (SDUT) – School of Light Industry and Agricultural Engineering (Zibo, Shandong, China)**

Main goal	Biomass (fast, flash, plasma heated) pyrolysis technology for liquids (bio-oil) production. Biomass includes: corn stover, corn stalks, cotton stalks.
Type BR	Lignocellulosic feedstock biorefinery
Time status	
Budget	
Website	www.sdut.edu.cn
Source	SDUT Natural Science Research; Xiu, 2005; Wang, 2006b; Yi, 2008; Zheng, 2008

* Name **Shanghai Jiaotong University (SJTU) – School of Mechanical and Power Engineering (Shanghai, China)**

Main goal	Pyrolysis of rice stalks
Type BR	
Time status	
Budget	
Website	www.sjtu.edu.cn
Source	Duan, 2007

* Name **Shihezi University – Laboratory for Green Chemical Technology (Shihezi, Xinjiang, China)**

Main goal	Fast conversion of glycerol into 1,3-propanediol
Type BR	Oilseed biorefinery
Time status	
Budget	
Website	www.studymbbsinchina.com
Source	Zhang, 2007b

* Name **Sichuan University (SCU) (Chengdu, Sichuan, China)**

Main goal	Preparation of biodiesel from waste restaurant grease by acid catalyzed two-step raising temperature process
Type BR	Oilseed biorefinery
Time status	
Budget	
Website	www.scu.edu.cn (Chinese language)
Source	Li, 2008

*	Name	**South China University of Technology (SCUT) – State Key Laboratory of Pulp and Paper Engineering (Guangzhou, Guangdong, China)**
	Main goal	Isolation and modification of cellulose and hemicellulose from biomass • Isolation of cellulose from sugarcane bagasse using ultrasound • Organosolv lignins from wheat straw • Use of hemicellulose in papermaking • Etherification of hemicelluloses from sugarcane bagasse (to make hemicellulose more hydrophobic and more useful in industrial applications) • Development of cationic polymers from hemicellulose • Rapid esterification of wheat straw hemicelluloses induced by microwave irradiation (to make hemicellulose more hydrophobic and more useful in industrial applications)
	Type BR	Lignocellulosic feedstock biorefinery / biochemical pathway
	Time status	
	Budget	
	Website	en.scut.edu.cn
	Source	State Key Laboratory of Pulp and Paper Engineering; Int Conf on Biorefinery, 2007; Sun, 2002; Liu, 2006; Xu, 2006; Ren, 2006; Ren, 2007; Ren, 2007b; Xu, 2008; Jiang, 2009

*	Name	**Tianjin University (TJU) – Department of Environmental Science and Engineering, Department of Biochemical Engineering (Tianjin, China)**
	Main goal	Activities include: • Development of succinate production • Light aromatic hydrocarbons from (woody) biomass by catalytic pyrolysis
	Type BR	Lignocellulosic feedstock biorefinery / Biochemical pathway
	Time status	
	Budget	
	Website	www.tju.edu.cn
	Source	Wang, 2006; Wang, 2008

*	Name	**Tianjin University of Science and Technology (TUST) – Department of Environmental Science and Engineering (Tianjin, China)**
	Main goal	Production of Light Aromatic Hydrocarbons and other chemicals from Biomass by Catalytic Pyrolysis
	Type BR	Lignocellulosic feedstock biorefinery, using dual-particle powder fluidized bed
	Time status	
	Budget	
	Website	www.tust.edu.cn
	Source	Chang, 2008; Liu, 2008

*	Name	**Tsinghua University – Department of Chemical Engineering (Beijing, China)**
	Main goal	Developing genetically-based bioproducts and bioprocesses by: • enzymatic technology and bioreactors; • optimization of fermentation, large scale hybridoma cell culture; • metabolic engineering Pretreatment of lignocellulosic biomass for enzymatic hydrolysis. Biodiesel production from oil crops (rapeseed, soybean oil, waste oil, jatropha oil) in supercritical and subcritical methanol.
	Type BR	Lignocellulosic feedstock biorefinery / biochemical pathway
	Time status	
	Budget	
	Website	www.tsinghua.edu.cn
	Source	Zhuan Cao; Sun, 2006; Liang, 2007; Wang, 2007c; Tang, 2007; Yu, 2010

*	Name	**University of Science and Technology of China (USTC)** (established by Chinese Academy of Sciences) **(Hefei, Anhui, China)**
	Main goal	Pyrolysis of rice husks and sawdust to liquid fuel
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	en.ustc.edu.cn
	Source	Zheng, 2006

*	Name	**Zhejiang University (ZJU) – Department of Chemical and Biochemical Engineering, Institute of Bioengineering (Hangzhou, Zhejiang, China)**
	Main goal	• Direct acrylic acid fermentation from biomass • Production of acrylates from lactic acid or methyl lactate • Butyric acid fermentation from cane molasses in a fibrous bed bioreactor
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.zju.edu.cn
	Source	Xu, 2006b; Zhang, 2008; Zhang, 2008b; Jiang, 2009

*	Name	**Zhejiang University of Technology (ZJUT) – Institute of Bioengineering, State Key Laboratory of Clean Energy Utilization (Hangzhou, Zhejiang, China)**
	Main goal	• Biocatalysis: Microbial transformation of biochemical compounds • Biomass flash pyrolysis for bio-oil production
	Type BR	
	Time status	
	Budget	
	Website	www.zjut.edu.cn
	Source	Yuguo Zheng, 2007; Jing Chen, 2009; Wang, 2007b; Wang, 2008b; Zheng, 2008;

6.3.2 India

*	Name	**Agharkar Research Institute (ARI) (Pune, Maharashtra, India)**
	Main goal	• Biogas production from dung and distillery waste: selection and evaluation of anaerobic bacteria, and development of microbial removal of hydrogen sulfide from biogas • Developing a microbial process for degradation of organic halides (AOX) from pulp of paper mill effluent
	Type BR	Biochemical pathway
	Time status	
	Budget	
	Website	www.aripune.org
	Source	ARI biogas

*	Name	**Birla Institute of Technology – Department of Biotechnology (BIT) (Ranchi, Jharkhand, India)**
	Main goal	Simultaneous saccharification and fermentation of aqueous ammonia-pre-treated sugarcane for ethanol production
	Type BR	Lignocellulosic feedstock biorefinery / Biochemical pathway
	Time status	
	Budget	
	Website	www.bitmesra.ac.in
	Source	Zhang, 2009; BIT biotechnology research

*	Name	**DBT-Institute of Chemical Technology (ICT), Centre for Energy Biosciences (Mumbai, India)**
	Main goal	• Development of technologies for fractionation of lignocelluloses in ways that facilitate subsequent bioconversion of cellulose and hemicelluloses to fermentable sugars that in turn will be converted to alcohol. • Enzyme technology: immobilization of enzymes, a.o. lipases and glucose oxidases; development of strains for biodiesel production from vegetable oils • Fermentation technology: a.o. ethanol and butanol • Separation technology: design of adsorbents for selective separation of biomolecules; chromatographic separation; affinity precipitation.
	Type BR	Lignocellulosic feedstock biorefinery / Biochemical pathway; Oilseed biorefinery; Marine biorefinery
	Time status	
	Budget	
	Website	www.ceb.org.in
	Source	ICT research areas

*	Name	**Indian Institute of Technology – Department of Biotechnology (IIT) (Chennai, Tamilnadu, India)**
	Main goal	• Production of medium-chain-length poly(3-Hydroxyalkanoates) from crude fatty acid • Biogas production from mixed-acid waste from domestic waste
	Type BR	Biochemical pathway
	Time status	
	Budget	
	Website	www.iitm.ac.in; www.biotech.iitm.ac.in
	Source	IIT PHA from crude fatty acids; Annuar, 2007; Vadlani, 2008

* Name **Jawaharlal Nehru Technological University – Department of Biotechnology (JNTU) (Hyderabad, Andhra Pradesh, India)**
Main goal Simultaneous saccharification and fermentation of aqueous ammonia-pre-treated sugarcane for ethanol production
Type BR Lignocellulosic feedstock biorefinery / Biochemical pathway
Time status
Budget
Website www.jntu.ac.in
Source Program Biorefinery Conference, 2009

* Name **K.J. Somaiya Institute of Applied Agriculture Research (KIAAR)** - R&D organization of Godavari Biorefineries Ltd **(Mumbai, India)**
Main goal Working on biodiesel production from non-edible oil containing intercrops like Castor and Mesta/Roselle.
Type BR Oilseed biorefinery
Time status
Budget
Website KIAAR homepage
Source KIAAR biodiesel

* Name **National Chemical Laboratory (CSIR / NCL) (Pune, Maharashtra, India)**
Main goal
- Fractionation of biomass (bagasse) into cellulose, hemicellulose and lignin using steam explosion.
- Production of cellulose acetate from cellulose extracted from bagasse.
- Catalyst for production of biodiesel from Jatropha, Karanja and unrefined rubber seed oil.
- Zeolite for conversion of methane (biogas) into gasoline-range hydrocarbons

Type BR Lignocellulosic feedstock biorefinery
Time status
Budget
Website www.ncl-india.org
Source NCL press release; NCL research projects; Shaikh, 2009; Varma, 2007; NCL catalyst for biodiesel production; NCL zeolite for methane into gasoline conversion

* Name **National Institute for Interdisciplinary Science and Technology** (formerly Regional Research Laboratory) **– Biotechnology Division (CSIC / NIIST) (Trivandrum, Kerala, India)**
Main goal
- Key competences: microbial technology, enzyme technology and fermentation technology. Claiming to be world leader in solid state fermentation.
- Bioethanol from lignocellulose biomass: pretreatment, cellulase production, fermentation of pentose, process integration. Sources: rice and wheat straw, sugarcane bagasse.
- Production of L(+) lactic acid from agro-residues
- Production of polyhydroxy butyrate (PHB) from glycerol
- Protein based bio-pesticides

Type BR Lignocellulosic feedstock biorefinery; Oilseed biorefinery / Biochemical pathway
Time status
Budget
Website www.niist.res.in
Source NIIST Biotechnology research overview;

*	Name	**Osmania University Technology – Department of Microbiology (Hyderabad, Andhra Pradesh, India)**
	Main goal	• Acid hydrolysis of lignocellulosic feedstock for bioethanol production. • Simultaneous saccharification and fermentation of aqueous ammonia-pre-treated sugarcane for ethanol production
	Type BR	Lignocellulosic feedstock biorefinery / Biochemical pathway
	Time status	
	Budget	
	Website	www.osmania.ac.in
	Source	Program Biorefinery Conference, 2009; Chandel, 2007
*	Name	**Reliance Industries Limited (RIL) (Mumbai, India)**
	Main goal	Consolidated Bio Processing (CBP): Cellulose hydrolysis, pentose and glucose fermentation
	Type BR	Lignocellulosic feedstock biorefinery / Biochemical pathway
	Time status	
	Budget	
	Website	www.ril.com
	Source	RRB conference, 2006
*	Name	**The Energy and Resources Institute (TERI) (New Delhi, India)**
	Main goal	• Lignin dissolution and hydrolysis of crystalline cellulose • Methane from organic solid waste, comprising an acidic pretreatment and anaerobic methanation
	Type BR	Lignocellulosic feedstock / biorefinery Biochemical pathway
	Time status	
	Budget	
	Website	www.teriin.org
	Source	TERI project 1; TERI project 2

6.3.3 Japan

*	Name	**Central Research Institute of Electric Power Industry (CRIEPI) (Abiko, Japan)**
	Main goal	Innovative thermal power generation technologies, such as biomass gasification and coal-based Integrated Gasification Combined Cycle (IGCC).
	Type BR	Thermochemical pathway / syngas platform biorefinery
	Time status	
	Budget	
	Website	criepi.denken.or.jp
	Source	BiorefInteg, 2009-p38; IGCC activities, 2010

*	Name	**Hiroshima University – Department of Molecular Biotechnology (Hiroshima, Japan)**
	Main goal	Studying anaerobic microorganisms, photosynthetic bacteria, yeast and micro flora that play an important role in biotechnological processes such as wastewater treatment and useful material production. The following themes are studied in particular: • Hydrogen-Methane fermentation from sugar-rich wastewaters, bread wastes and biodiesel wastewaters • Dry ammonia-methane fermentation of cow and chicken feces and food waste • Direct conversion of cellulose into methane • Carotenoid production by microalgae and yeast • Vitamin B12 production by anaerobic microorganisms • Hydrogen and solvent production from waste • Chiral compound conversion in anaerobic microorganisms
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.hiroshima-u.ac.jp
	Source	Department of Molecular Biotechnology; Tjahjono, 1994; Nakashimada, 2000; Nakashimada, 2003; Nishio, 2004; Nishio, 2007

*	Name	**Kansai Electric Power Co (Osaka, Japan)**
	Main goal	Co-production of carbon nanotubes and hydrogen via catalytic decomposition of methane
	Type BR	
	Time status	
	Budget	
	Website	www.kepco.co.jp
	Source	Kansai R&D-project, 2010

*	Name	**Kyoto University – Graduate School for Energy Science (Kyoto, Japan)**
	Main goal	The projects focus on supercritical fluid science and technology, aiming at a variety of biofuel production technologies though: • Decomposition of lignin into dimeric compounds and cellulose into levoglucosans, using supercritical methanol treatment • Turning crystalline structure of cellulose into amorphous structure using supercritical water treatment (amorphous cellulose is more easily accessible for further hydrolysis and fermentation to bioethanol) • Supercritical methanol process in which all fatty acids are converted into

FAME (In a conventional biodiesel process, free fatty acids, making up to 25% of waste oils, are converted into products that can not be recovered and as such are wasted)
- Supercritical methyl acetate process in which oils are converted into FAME, and where triacetin instead of glycerin is produced as a co-product. Whereas glycerin has to be removed and has low commercial value, triacetin may be used as an additive to biodiesel.

Also Shiro Saka's group works on indirect fermentation through acetic acid fermentation, thus obtaining higher overall ethanol yield.

Type BR: Lignocellulosic feedstock biorefinery; Oilseed biorefinery; lignin platform
Time status:
Budget:
Website: www.kyoto-u.ac.jp; www.energy.kyoto-u.ac.jp
Source: BiorefInteg, 2009-p71-77; Saka, 2009

* Name: **Kyushu University (Fukuoka, Japan)**
Main goal: An ionic liquid and a cellulase that allow enzymatic saccharification of a model cellulose substrate in one step into glucose and cellobiose.
Type BR: Lignocellulosic feedstock biorefinery
Time status:
Budget:
Website: www.kyushu-u.ac.jp
Source: R1-p25; Kamiya, 2008;

* Name: **Nagoya University – School of Engineering (Nagoya, Japan)**
Main goal: Novel strategies to engineer functional proteins (enzymes) using high-throughput screening assisted with fuzzy neural network
Type BR:
Time status:
Budget:
Website: http://www.nagoya-u.ac.jp/en/
Source: Nagoya University Research; Kato, 2005

* Name: **National Institute of Advanced Industrial Science and Technology (AIST) (Tsukuba & Tokyo, Japan)**
Main goal: AIST conducts research that transcends the barriers between disciplines. AIST cover six research fields, including "Life Science and Biotechnology", "Nanotechnology, Materials and Manufacturing", and "The Environment and Energy".
In particular:
- Development of processes to convert biomass into ethanol, ETBE and polymers by using mechanochemical and hydrothermal processes and enzymatic saccharification.
- Biomass conversion systems simulations

Type BR: Lignocellulosic feedstock biorefinery
Time status:
Budget:
Website: www.aist.go.jp
Source: AIST Laboratories; AIST Biomass Research themes; Yu, 2010

*	Name	**Niigata University – Department of Materials Science and Technology (Niigata, Japan)**
	Main goal	Production of D-, and L-lactic acid from rice bran by simultaneous saccharification and fermentation.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.niigata-u.ac.jp
	Source	Taniguchi, 2005; Tanaka, 2006

*	Name	**Oita University – Department of Applied Chemistry (Oita, Japan)**
	Main goal	Production of D-, and L-lactic acid from rice bran by simultaneous saccharification and fermentation.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.oita-u.ac.jp
	Source	Taniguchi, 2005; Tanaka, 2006

*	Name	**Research Institute of Innovative Technology for the Earth (RITE) – Molecular Microbiology and Biotechnology Group (Kyoto, Japan)**
	Main goal	• With Honda: Ethanol from waste biomass such as leaves, discarded wood and other non-edible plant materials. Mixed sugars are converted using by genetically engineered *Coyrnebacterium glutamicum* • production of valuable chemicals from biomass
	Type BR	Lignocellulose feedstock biorefinery
	Time status	
	Budget	
	Website	www.rite.or.jp
	Source	Rite-Honda announcement, 2008; RITE Research areas ; RITE Biorefinery Research

*	Name	**Shizuoka University – Department of Applied Biological Chemistry (Shizuoka, Japan)**
	Main goal	• Riboflavin production from waste activated bleached earth containing rapeseed oil • Enhancement of lipase catalyzed-fatty acid methyl esters production from waste activated bleaching earth
	Type BR	Oilseed biorefinery
	Time status	
	Budget	
	Website	www.shizuoka.ac.jp
	Source	Ming, 2003; Dwiarti, 2010

*	Name	**Toyama University – Department of Materials Systems Engineering and Life Science (Toyama, Japan)**
	Main goal	Production of D-, and L-lactic acid from rice bran by simultaneous saccharification and fermentation.
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	
	Budget	
	Website	www.u-toyama.ac.jp
	Source	Taniguchi, 2005; Tanaka, 2006

*	Name	**University of Tokyo – Marine Science and Technology, Mitsubishi Research Institute, Mitsubishi Heavy industries, and others [1] (Japan)**
	Main goal	Enzymatic conversion of Sargasso seaweed (Fucoidan and Alginic Acid) into sugars for bioethanol production.
	Type BR	Marine biorefinery (Macro algae)
	Time status	
	Budget	
	Website	www.u-tokyo.ac.jp; www.mri.co.jp; www.mhi.co.jp; Masami, 2008
	Source	BiorefInteg, 2009-p52; Blogonsmog, 2009; JFS, 2008

*	Name	**University of Tokyo (Tokyo, Japan)**
	Main goal	Isolation of furfural from rice husk, using a membrane reactor under hydrothermal conditions
	Type BR	Thermochemical pathway / syngas platform biorefinery
	Time status	
	Budget	
	Website	www.u-tokyo.ac.jp
	Source	BiorefInteg, 2009-p48; Mochidzuki, 2005

*	Name	**University of Tsukuba – Institute of Applied Biochemistry (Tsukuba, Japan)**
	Main goal	Renewable energy production from agricultural wastes.
	Type BR	
	Time status	
	Budget	
	Website	www.agbi.tsukuba.ac.jp; www.tsukuba.ac.jp
	Source	Wageningen UR (Jan van Dam) internal note, no further details found.

[1] NEC Toshiba Space Systems, Mitsubishi Electic, IHI, Sumitomo Electric Industries, Shimizu Corporations, Toa Corporation, Kanto Natural Gas Development Co. Ltd., and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC).

6.4 Pilot plants Asia

6.4.1 China

*	Name	**Dongping plant (Dongping, China)**
	Name pilot	Located in Dongping
	Description	Integrated utilization of straw: fractionation of straw into cellulose (3000 t/a solid state fermentation into ethanol pilot plant), xylo-oligosaccharides, bio-organic fertilizer.
	Feedstock	Cellulose from straw
	Products	Ethanol
	Type BR	Lignocellulose feedstock / biochemical pathway
	Time status	Set up in 2008.
	Budget	
	Website	
	Source	Tianwei Tan, 2009; IPE-CAS Straw ethanol plant

Commercial:

*	Name	**Gushan Environmental Energy (Mianyang, Sichuan, China)**
	Name pilot	
	Description	Largest biodiesel producer in China: 5 plants in Sichuan, Hebei, Fujian provinces and in Beijing and Shanghai
	Feedstock	Vegetable oil waste and used cooking oil
	Products	Biodiesel 340,000 tons/a
	Type BR	Oilseed biorefinery
	Time status	In operation, additional 60,000 tons/a planned
	Budget	
	Website	www.chinagushan.com/en
	Source	BiorefInteg, 2009-p10

*	Name	**COFCO (Beijing, China)**
	Name pilot	
	Description	Ethanol plant
	Feedstock	Cassava
	Products	Ethanol 400,000 tons/a
	Type BR	Lignocellulosic feedstock biorefinery / Biochemical pathway / sugar platform
	Time status	planned
	Budget	
	Website	
	Source	BiorefInteg, 2009-p18; Cofco, 2010

*	Name	**Tianguan Group (Nanyang City, Henan, China)**
	Name pilot	
	Description	Plants for: bioethanol from wheat and from cellulose; biogas; 1,3-propanediol; biodegradable polyvinylalcohol; glacial acetic acid. Claiming to be the biofuel developing centre in China.
	Feedstock	Wheat, biomass
	Products	Fibre ethanol 300,000 tons/a; biodiesel 100,000t/a; biogas 150,000,000 m^3; biochemicals 200,000 t/a; biodegradable polymers (PVA ?, PPC ?) 200,000 t/a
	Type BR	Lignocellulosic feedstock biorefinery / Biochemical pathway / sugar platform
	Time status	In operation
	Budget	
	Website	www.tianguan.com.cn
	Source	BiorefInteg, 2009-p33; Tianguan - Science; Tianguan - Company brief; Tianwei Tan, 2009

6.4.2 India

*	Name	**Godavari Sugar Mills Ltd (Sameerwadi, Karnataka, India)**
	Name pilot	
	Description	Project together with CSIR - NCL
	Feedstock	Bagasse, 5000 tons of bagasse in 4 years.
	Products	Cellulosic ethanol. Also paper, cardboard, textiles, water-soluble adhesives.
	Type BR	Lignocellulosic feedstock
	Time status	
	Budget	
	Website	www.somaiya.com
	Source	McDermott, 2009 ; Koshy, 2008; Products from sugarcane flow chart

*	Name	**National Institute for Interdisciplinary Science and Technology – Biotechnology Division, Centre for Biofuels (CSIC / NIIST) (Trivandrum, Kerala, India)**
	Name pilot	
	Description	Bioethanol production technology using select feedstock
	Feedstock	Various lignocellulose sources
	Products	Bioethanol
	Type BR	Lignocellulosic feedstock / Biochemical pathway
	Time status	Under construction
	Budget	
	Website	www.niist.res.in
	Source	NIIST Centre for Biofuels pilot

*	Name	**Thar Technologies (Jaipur, Rajasthan, India)** (probably a commercial pilot)
	Name pilot	
	Description	CO_2 (instead of hexane) extraction of oil from oil seeds
	Feedstock	Karanj, Jatropha
	Products	Biodiesel
	Type BR	Oilseed biorefinery
	Time status	
	Budget	
	Website	www.tharsfc.com
	Source	Anouncement, 2008

6.4.3 Japan

*	Name	**BioEthanol Japan (Osaka, Japan)**
	Name pilot	Sakai plant
	Description	Dilute sulfuric acid used to hydrolysis of cellulose, and use conventional yeast for 6-carbon sugars and a genetically modified Escherichia coli for 5-carbon sugars. In 2007, the plant fermented only 6-carbon sugars made from hemicellulose, planning to use an enzyme modified to decompose cellulose as well.
	Feedstock	Wood debris
	Products	Bioethanol, 1.4 million liter/year
	Type BR	Lignocellulosic feedstock
	Time status	Started operation in January 2007
	Budget	
	Website	www.bio-ethanol.co.jp (Japanese)
	Source	BiorefInteg, 2009-p35; Ethanol producer magazine, 2007; Tanaka, 2007; www.tsk-g.co.jp

7 Brazil

7.1 Introduction

The development of fuel ethanol production from sugar cane has been given a boost by the ProAlcool program initiated in Brazil in the 1970s. The main motivations for launching the program were the dramatic increase of petrol price in a context of high external dependency and the deficit in Balance of Payments. When a second oil price shock came in 1979, Brazilian government promoted the development of new plantations and the development of ethanol-fueled vehicles. At a certain moment of time, when oil prices levelled off, fuel ethanol margins decreased, and disputes between Government and producers on price controls caused a reduction of subsidies. As a result ethanol production decreased and supply could not fulfil the demand. As a consequence, consumers hesitated to buy new ethanol fueled cars, and the interest in ProAlcool deteriorated. In 1993 blending of ethanol and gasoline became mandatory. In the late 1990s the government deregulated the fuel ethanol business and instituted taxes that only apply for fossil gasoline and diesel. In 2003 a flex-fuel car has been introduced which can run on both 100% gasoline and 100% ethanol and any mixture in between. In May 2005, flexi-fuel vehicle sales exceeded gasoline fueled vehicle sales. In 2007 19 billion litres of fuel ethanol were produced in Brazil. Fuel ethanol production costs are such that ethanol has a price advantage if oil prices are above US$ 35/barrel (Garten Rothkopf, 2007; Elbersen, 2008; Biorefinery Euroview, 2008).

In 2004 the National Biodiesel Production Program (PNPB) was created to promote domestic biodiesel production, generate jobs and income and alleviate regional economic disparities through inclusion of family farmers, especially those in North and Northeastern Brazil. Feedstock for biodiesel production include vegetable oils, animal fats, fried oil and others. Over the period 2006-2009, soybean oil represented 81% of the biodiesel feedstock, animal tallow 16% (Barros, 2009).
Biodiesel production remains regulated by the Brazilian Government through a public auction system which sets the volume of biodiesel that should be produced and delivered to fuel distributors in a particular period of the year, as well as average sales price. Producers are not allowed to change the sales price set at the auctions and consequently must search for low cost raw material and/or hedge their activities to offset risk.
As of 1 July 2009, a 4 percent blend of biodiesel in mineral diesel (B4) for fuel use became mandatory. According to the current legislation, the required blend will rise to five percent (B5) in 2013, but it will likely happen quite before that point in time. Industry leaders claim that B5 could already be adopted in 2010 as the industry has overcome the initial production and logistical obstacles and it has overcapacity to produce and meet the required demand (Barros, 2009).

The biodiesel “Social Fuel Stamp” is a mechanism created by the Brazilian Government to provide incentives for poorer farmers (family farmers) in disadvantaged areas. Resolution #01 and #02 of 2005 set by the Ministry of Agrarian Development state that biodiesel producers must comply with the following requirements to obtain the stamp:

- purchase minimum raw material percentages from family farmers;
- guarantee the purchase of available quantities;
- set contracts with farmers, provide technical assistance and training.

The minimum percentages that must be purchased from family farmers vary according to region and are currently set at 30 percent for the Northeast, Southeast and Southern regions; 10 percent for the Center-West and North for the 2009/10 crop and 15 percent for the Center-West and North for the 2010/11 crop (Resolution #01 of 25 February 2009) (Barros, 2009).

The fuel ethanol and biodiesel development in Brazil has been mainly financed by private companies. In OECD countries about 67% of overall R&D activities are performed by industry, while in Brazil only 11% of all scientists operate in the business sector. However, the majority of ethanol and biodiesel research and development in Brazil is financed and conducted by private companies (Garten Rothkopf, 2007).

New developments in Brazilian fuel ethanol include breeding of cane varieties producing more biomass and ethanol production from the lignocellulosic fraction of the plant (Biorefinery Euroview, 2008).

Figure 8 Map Brazil (source: http://www.mapsofworld.com/brazil/brazil-political-map.html).

Other South American countries

According to a study by the Inter-American Institute for Cooperation on Agriculture (IICA) all countries in South America have research centres that are addressing various aspects of feedstock production for biofuels. However, only a few countries host institutes that are performing research and innovation for actual ethanol production: Brazil, Argentina, Colombia, and Mexico (Seixas, 2007). Zuurbier (2010) adds that also Chile and Ecuador have their national agencies which put efforts into biofuel research.

Biofuels R&D budgets are much larger in Brazil than in Argentina, which are significantly larger than in other South American countries (Garten Rothkopf, 2007). Because of limited time available, in this project focus is on biorefinery R&D in Brazil only.

7.2 Funding programmes Brazil

*	Name FA	**Brazilian National Development Bank (BNDES)**
	Name FP	• Investment Fund Program (1 call focusing on Biotechnology) • Technology Fund (FUNTEC) (focus a.o. on renewable energy) • CRIATEC Program (focus on investment a.o. on Biotechnology) • Project Development Fund (FEP) (focus on social and economic trends) • Financial Support Program for Biodiesel Investments (closed)
	Main goal	• Investment Fund Program: Expand, through investment funds, the support to capitalization of business corporations of different sizes, also spreading out good governance practices and the risk capital culture in Brazil. • FUNTEC: Financial support for Bioenergy, focused on: a) Technologies to produce energy biomass targeted at increasing energy density and agricultural productivity in the following crops: sugar cane for ethanol, oilseeds for biodiesel, eucalyptus and other species for energy forests, fodder for energy production and microalgae; b) Improvements to the efficiency of industrial processes, aiming to increase productivity, cut down on costs and mitigate environmental impacts, as well as cleaner and cost-efficient technological routes related to the following processes: production of ethanol (distillation/fermentation/hydrolysis), biodiesel (transesterification), charcoal (pyrolysis), gasification of biomass, combustion, biodigestion and extraction of vegetal oils; and c) Technologies designed to re-use agricultural, forest and cattle-raising waste, including processes for waste collection, logistics and treatment (compacting, bricketing, drying and others). • d) Treatment of solid urban waste, focused on technological innovations in biodigestion processes. • e) Development of chemicals deriving from hydrolysis of biomasses (biorefineries), as well as developments connected to the production of ethanol by-products (alcohol chemistry). • CRIATEC: Investment in innovative companies operating in IT, Biotechnology, New Materials, Nanotechnology, Agribusiness and other sectors. • Project Development Fund: Support scientific and technical research, as well as technical studies, targeted at reporting social and economic trends, in order to allow the development of structuring projects to benefit society. • Program for Biodiesel Investments: Investing in all phases of biodiesel production, including R&D

	Time status	• Investment Fund Program • FUNTEC: Started in 2006 • CRIATEC: Started in 2007 • Project Development Fund: Started in 2008 • Program for Biodiesel Investments: Closed
	Budget	• Project Development Fund: R$ 20 million in 2008, equal to € 8 million • Program for Biodiesel Investments: US$ 5.7 million in 2004-2005
	Website	inter.bndes.gov.br
	Source	Garten Rothkopf, 2007; BNDES Programs; BNDES Investment Fund Program; BNDES Technology Fund; BNDES CRIATEC Program; BioDiesel program; BioDiesel Program 2
*	Name FA	**National Council for Scientific and Technological Development** (Conselho Nacional de Desenvolvimento Científico e Tecnológico, **CNPq**)
	Name FP	No particular program on biorefineries, rather focus on research supporting technological development beneficial to Brazil
	Main goal	General goal: Promotion of scientific and technological research and to the formation of human resources for research in Brazil. Offering grants and fellowships to researchers as well as masters, doctoral, and post-doctoral students in Brazil and abroad. Funding of institutions involved in R&I
	Time status	At least in period 2001 – 2006
	Budget	Overall CNPq € 330 million in 2005, €315 million in 2006, € 90 million in 2010.
	Website	www.cnpq.br (relevant sections in Portugese language only)
	Source	CNPq Programs; Landin, 2008; Garten Rothkopf, 2007; Zuurbier, 2010
*	Name FA	**National Fund for Scientific and Technological Development (FNDCT),** executive secretary of which is with Brazilian Innovation Agency (Financiadora de Estudos e Projetos, **FINEP**)
	Name FP	No particular program on biorefineries, but several funds could potentially be tapped for biofuels R&D funding, like e.g. CT-TRANSPORTE, CT-ENERG, ET-AGRO, CT-BIOTEC, GREEN-YELLOW
	Main goal	General goal: Encourage and finance innovation, and scientific and technological research in business, universities, institutes of technology, research centres, and other public or private institutions. The agency provides loans and grants, including for R&D projects as well as modernization of science and technological institutions' infrastructure.
	Time status	
	Budget	Overall FINEP € 620 million in 2006
	Website	www.finep.gov.br (in Portugese)
	Source	FINEP Brochure; FINEP paper; Landin, 2008; Garten Rothkopf, 2007

In Brazil, individual states also have their own funding programs which cover biorefinery R&D (see Appendix D). Each state its own network of state sponsoring and state universities and technology centres to focus on biofuels and biorefinery (Zuurbier, 2010).

7.3 Research organisations Brazil

*	Name	**BioEthanol Science and Technology Centre (CTBE) (Campinas, SP, Brazil)**
	Main goal	Mission of CTBE is to contribute for ensuring Brazilian leadership in the sustainable production of bioethanol from sugarcane through state-of-the-art research, development, and innovation. R&D topics include • Sugarcane biomass conversion to ethanol • Ethanol conversion to electrical or mechanical energy • Feedstock production: low impact mechanization • Bioethanol production: pilot plants for new processes • Research on social, environmental, and economic sustainability of very large scale sugarcane bioethanol production.
	Type BR	Lignocellulosic feedstock
	Time status	Centre started in 2008, fully in operation in 2011.
	Budget	R$ 20 million in 2009, equal to about € 8 million. Foreseen budget in 2011 is R$ 42 million, equal to € 17 million.
	Website	www.bioetanol.org.br
	Source	Cortez, 2008

*	Name	**Braskem (São Paulo, Brazil)**
	Main goal	• Developing polyethylene and polypropylene from bioethanol.
	Type BR	Lignocellulosic feedstock
	Time status	
	Budget	
	Website	www.braskem.com.br
	Source	Franco, 2009

*	Name	**CTC Canavieira (Piracicaba, SP, Brazil)**
	Main goal	Technological improvements including the use of selected yeasts to keep an accelerated pace in R&D projects aimed at optimizing the fermentation process. • Studies on the second generation ethanol (ethanol produced from bagasse); • Technological improvement to the Melle- Boinot process (batch with recycling of biomass); • Continuous fermentation process with serial vats; • Introduction of the bio-refinery concept to the Brazilian distilleries; • Hydrolysis, C5 fermentation.
	Type BR	Lignocellulosic feedstock
	Time status	
	Budget	
	Website	www.ctcanavieira.com.br
	Source	Franco, 2009; CTC Canavieira Projects; EU-KP7 Canebiofuel; Landin, 2008

*	Name	**Dedini (Piracicaba, SP, Brazil)**
	Main goal	Capital goods manufacturer, and world leader in the sugar-alcohol market. Experience in various areas such as: feasibility studies, initial process studies, engineering projects, erection supervision, start up and commissioning, supply of parts, components, equipment, plants and complete units, also under the turn-key system for market sectors including: Biodiesel, breweries, Energy & Cogeneration, Fertilizers, Food, Juice & Beverages, Petrochemical, Pulp & Paper, Sugar & Ethanol, Waste water treatment.
	Type BR	
	Time status	

	Budget	
	Website	www.codistil.com.br
	Source	Landin, 2008
*	Name	**Embrapa Agroenergia (Brasilia, DF, Brazil)**
	Main goal	Strategic objective of Embrapa is to speed up the Brazilian international leadership in this new economic sector of Bioenergy. The Embrapa's "Ethanol from lignocellulosic materials" project has the following objectives: a) to characterize and select alternative sources of biomass (sugar cane, sweet sorghum, wood, grass) with better characteristics for the production of lignocellulosic ethanol; b) to prospect and select microorganisms for the production of hydrolytic enzymes and for the alcoholic fermentation of sugars with five and six carbons; c) to prospect, synthesize and characterize genes involved in the synthesis of enzymes that hydrolyze cell walls to increase their specific activity or aiming at the consolidation of the conversion processes; and d) to develop more efficient conversion processes by using the improved raw materials, microorganisms and enzymes, for the sustainable production of ethanol from lignocellulosic materials. Also working on economical use of biodiesel production by-products.
	Type BR	Lignocellulosic feedstock
	Time status	
	Budget	
	Website	www.cnpae.embrapa.br (in Portugese)
	Source	Landin, 2008; Sundfeld, 2009; Machado
*	Name	**Laboratorio de Produtos Florestais do Serviço Florestal Brasileiro (LPF) (Brasilia, DF, Brazil)**
	Main goal	The Brazilian Forest Service is a federal agency responsible for implementing the sustainable forest management in all public forests at a federal level. The Brazilian Forest Service has its headquarters in Brasília, and it is represented over the whole country through its decentralized units. It also maintains a specialized research center, known as the Laboratory of Forest Products (LPF). The LPF is also part of Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA), which is under the Ministry of Environment. LPF was founded in 1973, with the objective of developing studies related to wood technology and other forest products and also for generating and transferring information and technology capable of encouraging sustainable development in the forest sector. Concerning the specific subject of wood residues compaction and charcoal, LPF has an industrial compaction plant to investigate the compaction possibility of any type of lignocellulosic residues, as well as to analyze quality of a large range of biomass.
	Type BR	Lignocellulosic Residues from Forestry
	Time status	
	Budget	
	Website	www.ibama.gov.br/lpf (in Portugese)
	Source	Bakker, 2010

*	Name	**Monsanto (acquired Allelyx and CanaVialis)**
	Main goal	Developing sugar cane varieties with high fibre content for lignocellulosic ethanol production
	Type BR	Lignocellulosic feedstock / Biochemical conversion
	Time status	
	Budget	
	Website	www.monsanto.com; www.alellyx.com.br; www.canavialis.com.br
	Source	Franco, 2009; Monsanto acquisition

*	Name	**Oxiteno (São Paulo, Brazil)**
	Main goal	• Lignocellulosic materials and its processing for production into bioethanol and chemicals using sugar and alcohol chemistry
	Type BR	Lignocellulosic feedstock
	Time status	
	Budget	R$ 6 million (1.5 by BIOEN, 1.5 by BNDES, 3 by Oxiteno), equal to about € 2.5 million
	Website	www.oxiteno.com.br
	Source	Franco, 2009; FAPESP-Oxiteno agreement; BIOEN announcement; Landin, 2008

*	Name	**Petrobras (Rio de Janeiro, Brazil)**
	Main goal	• Developing second generation ethanol technology, based on the mild acid hydrolysis pretreatment of bagasse, delignification, further cellulose depolymerization and fermentation. • Developing biodiesel from vegetable oils. Blending with diesel before the hydrotreating step (H Bio).
	Type BR	Lignocellulosic feedstock / Biochemical conversion
	Time status	
	Budget	
	Website	www2.petrobras.com.br
	Source	Franco, 2009; Petrobras Lignocellulosic Ethanol

*	Name	**Universidade de São Paolo - Esquola Superior de Agricultura, (Piracicaba, SP, Brazil)**
	Main goal	Wood energy, non-wood energy and charcoal
	Type BR	Lignocellulosic feedstock biorefinery (residues from sugar cane and forestry)
	Time status	
	Budget	
	Website	www.esalq.usp.br
	Source	ESALQ Forest sciences; Bakker, 2010

*	Name	**Universidade Estadual de Campinas (Unicamp) – Chemical Engineering School FEQ (Campinas, SP, Brazil)**
	Main goal	The Laboratory of Engineering of Fermentative and Enzymatic Processes (LEPFE) and the Laboratory of Optimization, Design and Advanced Process Control (LOPCA) have been working in partnership for many years and nowadays they have students working in collaboration in many subjects, among them the pretreatment and hydrolysis of lignocellulosic biomass and the process of bioethanol production. UNICAMP is a Brazilian leader in bioethanol production from lignocellulosic biomass, integrating physico-chemical pretreatments and enzymatic hydrolysis. Typically the research in hydrolysis and pretreatment cover the physical, chemical and enzymatic using sugar cane bagasse. Professor Maciel´s group has some collaborative research work with a European based company (Rhoune Poulenc, MG) which is mainly in the chemical product areas. Professor

		Telma Franco´s laboratory has mainly worked with fermentation, enzyme technology (synthesis and hydrolysis) and the modification and use of renewable resources. A topic is the use of our immense bioavailability of carbohydrates as substrate for several enzymatic and non-enzymatic reactions to produce new molecules. Also the fermentation potential of sugarcane hydrolysates to produce few other top-value interesting molecules (building blocks) which can be further used in the chemical industries is explored. Collaboration exists with Petrobras, some Brazilian cellulose and pulp industries, and Shell. In summary, the university works on: • New technologies 2nd generation bioethanol: strains selection, extractive fermentation, optimization, new enzymes, hydrolysis, pre-treatment • New technologies 2nd generation biodiesel: transesterification, optimization, microbial oil • Fast pyrolysis (BTL): bagasse, catalysis process • Hydrogen technology: production, purification, storage • Refinery flue gases and wastewater • Development of chemicals from saccharides
	Type BR	Lignocellulosic feedstock
	Time status	
	Budget	Various bilateral and unilateral projects
	Website	www.unicamp.br
	Source	Franco, 2009; Tsukamoto, 2008; Rob Bakker, 2010

*	Name	**Universidade Federal de Alagoas (Maceió, Alagoas, Brazil)**
	Main goal	Study the ethanolysis of castor and cottonseed oil into FAEE
	Type BR	Oilseed biorefinery
	Time status	
	Budget	
	Website	www.ufal.edu.br
	Source	BiorefInteg, 2009-p11

*	Name	**Universidade Federal do Paraná (UFPR) (Curitiba, Paraná, Brazil)**
	Main goal	Developing a cost-effective and industrially viable process for converting sugar cane bagasse and trash (i.e. sugar cane biomass) into fermentable sugars. Furthermore, the aim is to integrate such a process with existing production of 1st Generation ethanol based on sugar cane. A deeper knowledge about the structural components of sugar cane biomass will be investigated with the aim of capturing the easier fraction of the cellulose sugars.
	Type BR	Lignocellulosic feedstock
	Time status	1-3-2009 until 28-2-2011
	Budget	€ 2.49 million
	Website	www.ufpr.br (in Portugese)
	Source	EU-KP7 Energy-project ; EU-KP7 Canebiofuel

*	Name	**Universidade Federal de São Carlos (UFSCAR) – Chemical Engineering Department (São Carlos, SP, Brazil)**
	Main goal	Proteolysis of cheese whey with the aid of immobilized enzymes into whey protein hydrolysates for use as protein source for individuals with reduced capacity of digestion, or with genetic metabolic disorders (for instance phenylketonuria patients).
	Type BR	
	Time status	
	Budget	
	Website	www2.ufscar.br
	Source	Pinto, 2009

*	Name	**Universidade Federal de Viçosa (UFV) (Viçosa, MG, Brazil)**
	Main goal	Developing pre-treatments for optimized deconstruction of hybrid eucalyptus clones and elephant grass biomass into its components aimed at production of biofuel (bioethanol and biogas) along with specialty grade pulps and other bio-products, strongly emphasising feedstock selection and use of advanced analytical tools.
	Type BR	Lignocellulosic feedstock
	Time status	1-1-2010 until 31-12-2010
	Budget	€ 5 million
	Website	www.ufv.br
	Source	EU-KP7 Lignodeco

7.4 Pilot plants Brazil

*	Name	**CTBE's Pilot Plant for Process Development (PPDP) (Campinas, SP, Brazil)**
	Name pilot	PPDP
	Description	PPDP will be initially constituted by six conceptually integrated process modules, but with a high degree of operational flexibility (unitary operation possibilities): • physical treatment of lignocellulosic material • physical-chemical treatment of lignocellulosic material • production of microorganisms (fungi yeasts and bacteria) • enzymatic hydrolysis • extraction and purification • alcoholic fermentation The idea behind the flexibility of stand alone operation of the individual units is to increase the level of understanding between scientific and the industrial communities of the sector.
	Feedstock	Sugarcane bagasse
	Products	Ethanol
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	Announced, construction expected to be completed by early 2011
	Budget	CTBE will receive $25 million per year in government funding
	Website	www.bioetanol.org.br
	Source	FAPESP News, 2009; CTBE's Lignocellulosic ethanol pilot, 2010; PPDP Units

*	Name	**Dedini S/A & Centro de Tecnologia Canavieira (CTC) (Pirassununga, SP, Brazil)**
	Name pilot	
	Description	Conversion of bagasse into fermentable sugars using organosolv and acid hydrolysis process. 2 tons of biomass/day.
	Feedstock	Sugarcane bagasse
	Products	Ethanol
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	A 100 l/day pilot before 2004. A 5,000 l/day hydrolysis pilot in 2004
	Budget	
	Website	www.codistil.com.br
	Source	Bohlmann, 2006; FAPESP Online, 2007; CTBE Newsroom, 2009

*	Name	**Embrapa (Brasilia, Brazil)**
	Name pilot	
	Description	Focussing on finding enzymes and microorganisms involved in converting cellulosic feedstocks
	Feedstock	Cellulosic feedstock
	Products	Ethanol
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	Announced, construction to be completed by end of 2010
	Budget	
	Website	www.cnpae.embrapa.br (in Portugese)
	Source	CTBE Newsroom, 2009

*	Name	**Petrobras –** at its research centre **CENPES (Ilha do Fundão island, Rio de Janeiro, Brazil)**
	Name pilot	
	Description	Enzymatic hydrolysis of cellulosic feedstocks
	Feedstock	Cellulosic feedstock
	Products	Ethanol
	Type BR	Lignocellulosic feedstock biorefinery
	Time status	In operation in 2007
	Budget	
	Website	www2.petrobras.com.br
	Source	CTBE Newsroom, 2009; FAPESP News, 2009

Zuurbier (2010) mentions Unicamp and Braskem also having cellulosic ethanol R&D pilot plants.

8 Final remarks and recommendations

8.1 General remarks

Biorefinery R&D in most countries is mainly focussing on fuel (fuel ethanol and biodiesel) and energy (co-firing, biogas production), while only a very limited effort is spent on materials research. The only exception is the US where there is also more focus on bioproducts. Furthermore, it may be questioned whether focusing on the key-word 'biorefinery' will show all initiatives related to materials/chemicals development, as it is not certain whether researchers active in these fields consider themselves being active in the biorefineries R&D field.

Regarding the development of biofuels, most countries initiated policies which aim at the development of lignocellulosic ethanol production. Governments of countries like Australia, China and India also focus on the use of marginal lands for the production of non-edible oils for conversion into biodiesel.

8.2 Specific remarks per country

US
The focus is both on R&D and on scale-up (pilot, demo and pre-commercial) of biorefineries. Technology focus is on the thermochemical platform biorefinery (both gasification and pyrolysis) and the biochemical platform for a variety of feedstocks. Products are mainly mixed alcohols, hydrocarbons (bio-HCs) and bioproducts.

Canada
The main driver for biorefineries in Canada are finding new sustainable economic opportunities for forestry and agriculture industries and secondly rural economic development. Many projects are still in the pilot or R&D stage (not yet commercial). Mainly new technologies are being developed for typical Canadian lignocellulosic feedstocks (forest and agriculture). Also new industrial crops are being developed. Environmental implications are taken well into account.

Australia
There is substantial biobased products research and development activity in Australia. However, in 2007 the small Australian industry was still lagging behind other developed countries in terms of innovation and product range, and was mostly centred around biobased food packaging products (such as novel biodegradable polymers). The research and development covers the full range of activities from investigation of agronomic characteristics, of activities from investigation of agronomic characteristics of new industrial crops, examination of value chains for bio-based materials and development of novel materials from agricultural by-products and high value products from existing plants and genetically engineered varieties.

China

The country has a huge area of marginal land, 116 million ha, which may be used to grow crops for biofuel production. Not all initiatives can be found on the internet. For instance, employees of the Research Institute of Petroleum Processing (RIPP) of Sinopec, Beijing, publish on biorefinery in China (Min, 2005; Min, 2006), while the website of Sinopec does not refer to any such activities (english.sinopec.com). Also, three Chinese companies are reported to be experimenting with the production of biodiesel from "used" or "recycled" cooking oil and waste oilseeds (Mida Changhai, 2007), while not having a webpage at all:

- Hainan Zhenghe Bio-energy Co.'s factory in Wuan City, Hebei province
- Fujian Zhuoyue New Energy Development Corp.
- Sichuan Gushan Oil Chemical Co.

India
Already 80% of home energy use in India is biomass based.

Japan
Several Ministries (Environment, Agriculture, Economy) have different visions and approaches regarding the development and introduction of biofuels, each focussing on its own primary goals. The records described suggest that Japan is focussing more on materials than other countries.

Brazil
During the course of the subsequent fuel ethanol programs in Brazil, it became clear that over-regulation of the fuel ethanol business caused inflexible markets and brought the development to the edge of collapsing at the moment that fossil oil prices decreased too much. The current system including flexi-fuel-cars which may use any blend between 100% fossil based gasoline and 100% ethanol, allows the ethanol producers to optimize their ethanol production related to fluctuating fossil oil prices.

8.3 Recommendations

This document has collected much information that can be used during the StarCluster formation process. Some of the knowledge gaps identified in potential European Star projects could be filled by cooperating with an international research organisation described in this report. Using proven knowledge and technology (rather than starting new European projects to re-invent the wheel) might speed up the process of forming a complete StarCluster. During the process of identifying possible international comet projects this document could be searched for key-words, and the identified links could be studied to see if a certain international research organisation could be a valuable partner to the StarCluster. Therefore, the main advise is to use this document as an information portal to research knowledge outside the EU.

Apart from a brief description of each region/country studied, no further analysis of the data was made in this report although this could be very interesting. Therefore, it is recommended to partially perform this analysis in the further StarColibri project tasks during the StarCluster formation. The analysis could include e.g.: number of organisations working on biorefinery research, specific topics per region, cumulative budget spent, different feedstocks used, different technologies, preferred biorefinery types etc. However, it must be stated that further quantitative data probably will have to be collected (e.g. through contacting the organisations) in order to be able to perform a sound analysis.

This report of course only shows the status of biorefinery research at a certain moment in time. Therefore, it is recommended to repeat this type of survey regularly in the coming years. The report should be a living document that keeps track of changes in the international biorefinery research landscape. During the duration of the StarColibri project A+F will try to keep the document up-to-date as much as possible. However, after 2011 other projects will need to take over.

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Appendix A Biomass Project Fact Sheets US Department of Energy

Source: US DOE (2010)

U.S. Department of Energy - Energy Efficiency and Renewable Energy
Biomass Program

Biomass Project Fact Sheets
There are numerous facets to biomass research. The U.S. Department of Energy (DOE) Biomass Program consists of a large array of related but discrete projects covering various aspects of biomass feedstock generation and conversion technologies. DOE national laboratories conduct some projects; universities or other outside research organizations carry out others. Project selection also varies over time, with some projects taking only a year and others continuing for several. The following fact sheets summarize these various internal, external, and joint projects that make up the DOE Biomass Research Program.

Research and Development Project Fact Sheets

- Feedstocks
- Biochemical Platform Technology
- Thermochemical Platform Technology
- Integrated Biorefineries
- Biobased Products
- Congressionally Directed Projects

Feedstock Research Projects

- Active
  - Feedstock Infrastructure (PDF 79 KB)
  - Feedstock Supply Logistics (PDF 84 KB)
  - Multi-Component Harvesting of Wheat Straw (PDF 82 KB)
- Complete
  - Harvesting and Collection of Biomass (PDF 132 KB)
  - Selective Harvest of Wheat Straw (PDF 150 KB)
  - Biomass Bulk Processing and Storage (PDF 129 KB)
  - Feedstock Supply Forecasts and Analysis (PDF 121 KB)
  - Feedstock Supply System Logistics (PDF 132 KB)

Biochemical Platform Research Projects

- Active
  - Biochemical Platform Analysis (PDF 80 KB)
  - Biochemical Platform Processing Integration (PDF 127 KB)
  - Feedstock Sugar Interface (PDF 93 KB)
  - Integration of Biomass Pretreatment Technologies With Enzymatic Digestion and Hydrolyzate Fermentation (PDF 82 KB)
  - Pretreatment and Enzymatic Hydrolysis (PDF 85 KB)
  - Targeted Conversion Research (PDF 146 KB)
- Complete

- Biological Fractionation Fundamentals (PDF 137 KB)
- Biomass Structure (PDF 121 KB)
- Biomass Surface Characterization (PDF 124 KB)
- Chemical Processing Fundamentals (PDF 119 KB)
- Development of Improved Ethanol Fermentation Microorganisms (PDF 165 KB)
- Development of New Sugar Hydrolysis Enzymes: Genencor International (PDF 118 KB)
- Development of New Sugar Hydrolysis Enzymes: Novozymes Biotech, Inc. (PDF 130 KB)
- Emerging Pretreatment Options (PDF 105 KB)
- Enzymatic Biomass Conversion Process Integration (PDF 155 KB)
- Enzyme-Mediated Pretreatment (PDF 197 KB)
- Fundamental Study on Kinetics and Transport Phenomena in Low-Water, Dilute-Acid Total Hydrolysis of Cellulosic Biomass (PDF 284 KB)
- Fundamentals of Biomass Hydrolysis at Low pH (PDF 124 KB)
- Pretreatment of Applications for Corn Dry Mills (PDF 134 KB)

Thermochemical Platform Research Projects

- Active
  - Advancement of High-Temperature Black Liquor Gasification Technology (PDF 67 KB)
  - Biomass Gas Clean-Up Using a Therminator (PDF 78 KB)
  - Catalytic Hydrothermal Gasification of Wet Biomass Feedstocks (PDF 67 KB)
  - Causticizing for Black Liquor Gasifiers (PDF 67 KB)
  - Cost-Benefit Analysis of Fuel and Chemical Production at Pulp Mills (PDF 82 KB)
  - Direct Causticization for Black Liquor Gasification (PDF 68 KB)
  - Evaluation of Membrane Systems for Biomass Gasifiers (PDF 67 KB)
  - Feed Processing, Handling, and Gasification (PDF 76 KB)
  - Evaluation of Sulfur in Syngas (PDF 60 KB)
  - Fuel Chemistry and Bed Performance in a Black Liquor Steam Reformer (PDF 80 KB)
  - Gasification of Biorefinery Residues (PDF 60 KB)
  - Mixed Alcohols Production From Syngas (PDF 67 KB)
  - New Catalysts for In-Process Elimination of Tars (PDF 64 KB)
  - Pressurized Entrained-Flow Draft Black Liquor Gasification (PDF 75 KB)
  - Pyrolysis Oil Upgrading (PDF 68 KB)
  - Refractory for Black Liquor Gasifiers (PDF 76 KB)
  - Syngas Clean-Up and Conditioning (PDF 81 KB)
  - Thermochemical Conversion Analysis (PDF 104 KB)
  - Thermochemical Conversion of Corn Stover (PDF 69 KB)
  - Trace Metal Scavenging From Biomass Syngas Using Novel Sorbents (PDF 61 KB)
- Complete
  - Catalytic Cleanup Conditioning Fundamentals (PDF 121 KB)
  - Evaluation of RVS-1 Sorbent for Removal of Sulfur from Black Liquor Gasification (PDF 140 KB)
  - Fundamentals of Biomass Gasification (PDF 139 KB)
  - Gasification of Wet Biomass (PDF 135 KB)

- Materials Evaluation for Black Liquor and Biomass Gasifiers (PDF 105 KB)
- Pulsed Black Liquor Reformer Materials Evaluation (PDF 142 KB)
- Syngas Particulate Cleanup (PDF 111 KB)
- Thermochemical Process Modeling and Optimization (PDF 116 KB)

Integrated Biorefinery Research Projects

- Active
  - Abengoa Bioenergy Biomass, LLC Cellulosic Biorefinery (PDF 16 KB)
  - BlueFire Ethanol, Inc. Cellulosic Biorefinery (PDF 16 KB)
  - Poet (formerly Broin Companies) Cellulosic Biorefinery (PDF 16 KB)
  - Range Fuels (formerly Kergy Inc.) Cellulosic Biorefinery (PDF 16 KB)
  - Alltech Envirofine, LLC Ten Percent Scale Biorefinery (PDF 16 KB)
  - Flambeau River Biofuels LLC Ten Percent Scale Biorefinery (PDF 16 KB)
  - Lignol Innovations, Inc Ten Percent Scale Biorefinery (PDF 16 KB)
  - Mascoma Ten Percent Scale Biorefinery (PDF 16 KB)
  - NewPage Corp. Ten Percent Scale Biorefinery (PDF 16 KB)
  - Pacific Ethanol, Inc. Ten Percent Scale Biorefinery (PDF 16 KB)
  - Verenium Biofuels Corporation Ten Percent Scale Biorefinery(PDF 16 KB)
- Complete
  - Making Industrial Biorefining Happen (PDF 93 KB)
  - Integrated Corn-Based Biorefinery (PDF 145 KB)
  - Advancing Biorefining of Distiller's Grain and Corn Stover Blends (PDF 108 KB)
  - Big Island Demonstration Project - Black Liquor (PDF 647 KB)
  - Collection, Commercial Processing, and Utilization of Corn Stover (PDF 133 KB)
  - Enhancement of Co-Products From Bioconversion of Municipal Solid Waste (PDF 133 KB)
  - A New Biorefinery Platform Intermediate (PDF 77 KB)
  - A Second-Generation Dry Mill Biorefinery (PDF 73 KB)
  - Separation of Corn Fiber and Conversion to Fuels and Chemicals: Pilot-Scale Operation (PDF 84 KB)

Biobased Products Research Projects

- Active
  - Catalytic Upgrading of Glycerol to Propylene Glycol (PDF 170 KB)
  - Chemicals from Oilseeds (PDF 97 KB)
  - Engineering Thermotolerant Biocatalysts for Biomass Conversion to Products (PDF 126 KB)
  - Fungal Genomics (PDF 68 KB)
  - New Sustainable Chemistry for Adhesives, Elastomers, and Foams (PDF 95 KB)
  - Opportunity Analysis for Bio-Based Products (PDF 68 KB)
  - Platform Chemicals from an Oilseed Biorefinery (PDF 75 KB)
  - Production of Polyhydroxyalkanoate Polymers (PDF 71 KB)
  - Separative Bioreactor (PDF 113 KB)
  - Top Value-Added Chemicals from Biomass: Sugar, Syngas, and Lignin Pathways (PDF 80 KB)
  - Value-Added Products From Hemicellulose Utilization in Dry Mill Ethanol Plants (PDF 143 KB)

- Complete
  - Arabinose Yeast Cooperative Research and Development (PDF 150 KB)
  - Biocatalyst Development for Chemicals (PDF 155 KB)
  - Evaluation of Performance and Emission Benefits of Renewable Diesel Transportation Fuel (PDF 133 KB)
  - Functionalized Vegetable Oils for Use as Polymer Building Blocks (PDF 124 KB)
  - Pyrolysis Oil Upgrading for Products (PDF 129 KB)
  - Wood Adhesives from Bark-Derived Phenols (PDF 664 KB)

Congressionally Directed Projects

- Active
  - Agricultural Mixed Waste Biorefinery Using Thermal Conversion Process (PDF 249 KB)
  - Biomass-Derived Hydrogen from a Thermally Ballasted Gasifier (PDF 96 KB)
  - Energy from Biomass Research and Technology Transfer Program (PDF 153 KB)
  - Gasification-Based Fuel Conversion and Electricity Production in the Forest Products Industry (PDF 68 KB)
  - Gasification Research Center (PDF 88 KB)
  - Hybrid Poplar Research (PDF 92 KB)
  - Indiana Corn Dry Mill (PDF 72 KB)
  - Integration of Succinic Acid Production in a Dry Mill Ethanol Facility (PDF 86 KB)
  - Iowa Switchgrass Project (PDF 100 KB)
  - Kentucky Rural Energy Supply Program (PDF 89 KB)
  - Micro-Modular Biopower System for Cooling, Heating, and Power (PDF 87 KB)
  - Mississippi Ethanol Gasification Project (PDF 81 KB)
  - Native Flora Utilization (PDF 104 KB)
  - North Central Texas Dairy Waste Control Pilot Project (PDF 87 KB)
  - On-Farm Small-Scale Waste Energy Demonstration (PDF 97 KB)
  - Southeast Alaska Wood Residue Biorefinery (PDF 66 KB)
- Complete
  - AgraPure Mississippi Biomass Project (PDF 96 KB)
  - Black Belt Bioenergy Demonstration Project (PDF 94 KB)
  - North Country Hospital Biomass Conversion and Cogeneration Project (PDF 88 KB)
  - Salix Consortium: Energy Crops for Power Production (PDF 78 KB)

Appendix B US DOE recent funding advanced integrated biorefinery projects

Source: http://www.energy.gov/news2009/8352.htm & www.energy.gov/news2009/documents2009/564M_Biomass_Projects.pdf

In December 2009 the US Department of Energy (DOE) selected 19 integrated biorefinery projects to receive up to $564 million from the American Recovery and Reinvestment Act to accelerate the construction and operation of pilot, demonstration, and commercial scale facilities. The projects will validate refining technologies and help lay the foundation for full commercial-scale development of a biomass industry in the United States.

Of the nearly $564 million in Recovery Act funding, up to $483 million will go to 14 pilot-scale and 4 demonstration-scale biorefinery projects. The remaining $81 million will focus on accelerating the construction of a biorefinery project previously awarded funding. Collectively, these projects will be matched with more than $700 million in private and non-Federal cost-share funds, for total project investments of almost $1.3 billion.

The pilot scale projects include the following awards:

1. Algenol Biofuels Inc., project location Freeport TX—DOE grant amount $25,000,000. This project will make ethanol directly from carbon dioxide and seawater using algae.
2. American Process Inc., Alpena MI—$17,944,902. This project will produce ethanol and potassium acetate, a compound with many industrial applications, using processed wood generated by Decorative Panels International, an existing hardboard manufacturing facility in Alpena.
3. Amyris Biotechnologies, Inc., Emeryville CA—$25,000,000. This project will produce a diesel substitute through the fermentation of sweet sorghum.
4. Archer Daniels Midland, Decatur IL—$24,834,592. This project will use acid to break down biomass which can be converted to liquid fuels or energy. The ADM facility will produce ethanol and ethyl acrylate.
5. Clearfuels Technology Inc, Commerce City CO—$23,000,000. The project will produce renewable diesel and jet fuel from woody biomass by integrating ClearFuels' and Rentech's conversion technologies.
6. Elevance Renewable Sciences, Newton IA—$2,500,000. This project will complete preliminary engineering design for a future facility producing jet fuel, renewable diesel substitutes, and chemicals from plant oils and poultry fat.
7. Gas Technology Institute, Des Plaines IL—$2,500,000. This project will complete preliminary engineering design for a novel process to produce green gasoline and diesel from woody biomass, agricultural residues, and algae.
8. Haldor Topsoe, Des Plaines IL—$25,000,000. This project will convert wood to green gasoline by fully integrating and optimizing a multi-step gasification process.
9. ICM, Inc., Joseph MO—$25,000,000. This project will modify an existing corn-ethanol facility to produce cellulosic ethanol from switchgrass and energy sorghum using biochemical conversion processes.
10. Logos Technologies, Visalia CA—$20,445,849. This project will convert switchgrass and woody biomass into ethanol using a biochemical conversion processes.
11. Renewable Energy Institute International, Toledo OH—$19,980,930. This project will produce high quality diesel from agriculture and forest residues using advanced pyrolysis and steam reforming.

12. Solazyme, Inc., Riverside PA—$21,765,738. This project will validate the projected economics of a commercial scale biorefinery producing multiple advanced biofuels from algae oil.
13. UOP LLC, Kapolei HI—$25,000,000. This project will integrate existing technology from Ensyn and UOP to produce gasoline, diesel, and jet fuel from agricultural residue, woody biomass, dedicated energy crops, and algae.
14. ZeaChem Inc., Boardman OR—$25,000,000. This project will use purpose-grown hybrid poplar trees to produce fuel-grade ethanol using hybrid technology. Additional feedstocks such as agricultural residues and energy crops will also be evaluated.

The demonstration scale projects include the following awards:

1. BioEnergy International, LLC, Lake Providence LA—$50,000,000. This project will biologically produce succinic acid from sorghum. The process being developed displaces petroleum based feedstocks and uses less energy per ton of succinic acid produced than its petroleum counterpart.
2. Enerkem Corporation, Pontotoc MS—$50,000,000. This project will be sited at an existing landfill and use feedstocks such as woody biomass and biomass removed from municipal solid waste to produce ethanol and other chemicals through gasification and catalytic processes.
3. INEOS New Planet BioEnergy, LLC, Vero Beach FL—$50,000,000. This project will produce ethanol and electricity from wood and vegetative residues and construction and demolition materials. The facility will combine biomass gasification and fermentation.
4. Sapphire Energy, Inc, Columbus NM—$50,000,000. Additionally, the company received a loan guarantee for up to $54.5 million through the US Department of Agriculture's Biorefinery Assistance Program. This project will cultivate algae in ponds. The algae will ultimately be converted into jet fuel and diesel using the Dynamic Fuels refining process.

One award provides increased funding to existing biorefinery projects:

- Bluefire LLC, Fulton MS—$81,134,686. This project will construct a facility that produces ethanol fuel from woody biomass, mill residue, and sorted municipal solid waste.

Appendix C India state funding programs

Within the peninsula of India, individual states also have their own funding programs which cover biorefinery R&D. Example is indicated below.

*	Name FA	**Kerala State Council for Science, Technology and Environment (KSCSTE)** (formerly known as State Committee for Science, Technology and Environment (STEC))
	Name FP	• Engineering Technology Programs (EPS) • Science Research Scheme
	Main goal	Support of fundamental and applied R&D activities with particular relevance to the State of Kerala.
	Time status	Ongoing
	Budget	Up to INR 1 million (excluding overheads) for EPS-project of 3 years
	Website	www.kscste.kerala.gov.in
	Source	Engineering Technology Programs; Science research scheme

Appendix D Brazil state funding programs

Within Brazil, individual states also have their own funding programs which cover biorefinery R&D. Examples are indicated below.

* Name FA **São Paulo Research Foundation (Fundação de Amparo à Pesquisa do Estado de São Paulo, FAPESP)**

Name FP Bioenergy Research Program (BIOEN)

Main goal BIOEN aims at articulating public and private R&D, using academic and industrial laboratories to advance and apply knowledge in fields related to ethanol production in Brazil. BIOEN includes three subjects: Biomass to energy, Biofuel Production Processes, and Social, Economic and Environmental Impacts of Biofuels. Relevant topics for this call for research proposals are presented for each of these subjects below. The BIOEN Program will have other calls for grant applications in order to complement its research objectives and broaden its research topics.

1) Research on Biomass to Bioenergy

a. Structural and functional analysis and sequencing of genomes from species of interest for the production of biofuels.
b. Bioinformatics and computational tools for Systems Biology (genome analysis and integration, transcriptome, proteome and metabolome).
c. Trangênicos e estudos de estabilidade de transgenes.
d. Genetic modified organisms and transgene stability.
e. Molecular genetics of the plant development and hormonal signaling.
f. Photosynthesis and plant energy balance.
g. Plant nutrition.
h. Biogeochemistry.
i. Crop protection against insects and nematodes.
j. Plant pathology of the Brazilian germplasm.
k. Search and characterization of microorganisms with potential to make useful enzymes for biofuel production, especially cellulosic ethanol.
l. Enzyme engineering, structure and molecular evolution.
m. The use of sugarcane as a bioreactor.
n. Methods to enhance biomass processing.

2) Research on Biofuel Production Processes

a. Hydrolysis.
b. Gasification.
c. Other processes to produce biofuel from biomass.
d. New fermentation methods.
e. Genomics of microorganisms which are important for ethanol fermentation.
f. High-ethanol fermentation.
g. Search for combination of microorganisms for the extraction of sugars and for fermentation.
h. Metabolic engineering of microorganisms for production of metabolites that are relevant for the alcohol-chemical industry.
i. Energy integration and energy savings of ethanol distillation.
j. New strategies to control ethanol distillation.
k. Alternative technologies in ethanol concentration, purification and dehydration (membranes and other concentration methods).
l. Production processes of special alcohols for chemical, pharmaceutical, cosmetics and food industries.
m. Concentration and purification processes of minor compounds in

sugarcane wine.
n. Concentration and purification processes of other metabolites with industrial value.
o. Integration of the fermentation and pre-concentration steps in ethanol production.
p. Concentration and use of the sugarcane wine; reduction of the generation of waste products in the ethanol production.
q. Production of ethanol biodiesel and its integration with ethanol production.

3) Research on Social, Economic and Environmental Impacts of Biofuels

a. Land use.
b. Social impacts of biofuels.
c. Environmental impacts.
d. Environmental impacts of transgenic sugarcane.
e. Energy and carbon balance.
f. Global changes caused by the shift to new bioenergy sources.
g. Changes in agriculture caused by the competition between food and energy.
h. Limits to the expansion of arable land for energy crops in Brazil and in the world.
i. Intellectual property and technology transfer.

Time status	2 Calls closed on September 1st and November 10th 2008, respectively
Budget	R$ 5 million per call, equal to about € 2 million. Overall FAPESP € 210 million in 2006, € 320 million in 2010.
Website	www.fapesp.br
Source	FAPESP BIOEN Program; Landin, 2008; Zuurbier, 2010

* Name FA **Foundation for Support of Research of the State of Minas Gerais (Fundação de Amparo à Pesquisa do Estado de Minas Gerais, FAPEMIG)**

Name FP Programs are organized per type of project/cooperation, rather than per field of research and innovation

Main goal Central aim of FAPEMIG is the promotion of research and innovation in science and technology for the development of the state of Minas Gerais.
This is achieved by:

- Funding research projects in science and technology
- Encouraging the training of human resources for Science and Technology, through grants from various levels of training.
- Contributing to the establishment of groups of scientific and technological research.
- Promoting integration of the productive sector and research institutions and development.
- Supporting the development and organizes events of scientific and technological.
- Performing exchanges between Brazilian and foreign researchers, and establishing cooperation links with national and international institutions.
- Publishing research results.

Time status	In operation
Budget	Overall budget of FAPEMIG in 2008 was R$ 228 million, equal to about € 95 million
Website	www.fapemig.br (in Portugese)
Source	FAPEMIG annual report, 2008; Zuurbier, 2010

Many other state programs have run on e.g. biodiesel alone, see table below copied from page 461 of Garten Rothkopf, 2007.

Biofuels Research & Development projects by State

State	Program Title/Objective
Alagoas	Semi-arid Alagoano oil crops: technological innovation, sustainability and social inclusion
Amazonas	Insertion of the State of Amazonas into the national program for the production and use of biodiesel
Amapá	Research, development, and prospecting of native plants for the production of biodiesel in the Stae of Amapá
Bahia	Bahian biofuels network
Espírito Santo	Biodiesel in Espírito Santo
Goiás	Biodiesel program of Goiás
Maranhão	Special biodiesel program of Maranhão
Minas Gerais	Mineiro biodiesel program
Mato Grosso do Sul	Biodiesel program of the State of Mato Grosso do Sul
Mato Grosso	Biofuels program of Mato Grosso (PROBIOMAT)
Pará	Biodiesel production ion the State of Pará
Paraíba	Technological Network of PB-Biodiesel
Pernambucu	Technical-economic studies to consolidate industrial production processes for Castor-based biodiesel in Pernambuco
Piauí	Biofuels of Piauí: energy from Castor
Paraná	Paranaense bioenergy program: technical development of biodiesel
Rio de Janeiro	RioBiodiesel: clean and innovative fuel
Rio Grande do Norte	Potiguar biodiesel program: current situation
Rio Grande do Sul	PROBIODIESEL-RS project
Sergipe	Consolidate the technological and scientific base for processing and output of biodiesel
São Paulo	Biodiesel – SP project

Source: Brazilian Network of Biodiesel Technology