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IEA Bioenergieprogramm 2007-2009
Task 33: Thermische Vergasung von Biomasse

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Ein Bericht im Rahmen der Forschungskooperation Internationale Energieagentur

Im Auftrag des Bundesministeriums für Verkehr, Innovation und Technologie

Vorbemerkung

Der vorliegende Bericht dokumentiert die Ergebnisse eines Projekts aus dem Programm FORSCHUNGSKOOPERATION INTERNATIONALE ENERGIEAGENTUR. Es wurde vom Bundesministerium für Verkehr, Innovation und Technologie initiiert, um Österreichische Forschungsbeiträge zu den Projekten der Internationalen Energieagentur (IEA) zu finanzieren.

Seit dem Beitritt Österreichs zur IEA im Jahre 1975 beteiligt sich Österreich aktiv mit Forschungsbeiträgen zu verschiedenen Themen in den Bereichen erneuerbare Energieträger, Endverbrauchstechnologien und fossile Energieträger. Für die Österreichische Energieforschung ergeben sich durch die Beteiligung an den Forschungsaktivitäten der IEA viele Vorteile: Viele Entwicklungen können durch internationale Kooperationen effizienter bearbeitet werden, neue Arbeitsbereiche können mit internationaler Unterstützung aufgebaut sowie internationale Entwicklungen rascher und besser wahrgenommen werden.

Dank des überdurchschnittlichen Engagements der beteiligten Forschungseinrichtungen ist Österreich erfolgreich in der IEA verankert. Durch viele IEA Projekte entstanden bereits wertvolle Inputs für europäische und nationale Energieinnovationen und auch in der Marktumsetzung konnten bereits richtungsweisende Ergebnisse erzielt werden.

Ein wichtiges Anliegen des Programms ist es, die Projektergebnisse einer interessierten Fachöffentlichkeit zugänglich zu machen, was durch die Publikationsreihe und die entsprechende Homepage **www.nachhaltigwirtschaften.at** gewährleistet wird.

Dipl. Ing. Michael Paula
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Bundesministerium für Verkehr, Innovation und Technologie

Content

Kurzfassung

Das Ziel von IEA Bioenergy Task 33 „Thermische Vergasung von Biomasse“ ist es, Informationen über die Erzeugung von Heizgasen aus Biomasse für den Einsatz in umweltverträglichen, energieeffizienten und wirtschaftlich konkurrenzfähigen Energiebereitstellungssystemen auszutauschen. Dabei wird besonders auf den Informationsaustausch über die F&E Programme im Bereich Biomasse- und Reststoffvergasung, die kommerziellen Anlagen und die Marktchancen für Biomassevergasungssysteme Wert gelegt, um technische und nicht-technische Hürden zu identifizieren und zu beseitigen.

Die Tasks in IEA Bioenergy sind in Triennien organisiert und das letzte Triennium war von 2007 bis 2009. Die Arbeiten der Task 33 finden in Form von Meetings statt, wobei im letzten Triennium 6 Meetings mit jeweils einem Workshop zu einem Schwerpunkt abgehalten wurden. Die Minutes der Meetings sind auf der Homepage zu finden: http://www.ieatask33.org.

Österreich hat als Subtask Leader bei folgenden Projekten mitgearbeitet: (2007-2009):

- Country Reports
- Analysenmethoden zur Charakterisierung von Synthesegas
- Betriebserfahrungen von Biomassevergasungsanlagen

Zusätzlich ist Österreich noch aktiv an folgenden Projekten beteiligt, wie der Erstellung von Berichten über die Entwicklung der Biomassevergasung in den einzelnen Mitgliedsstaaten, der Standardisierung von Teer-Messungen, der Produktion von Wasserstoff und Wasserstoff reichem Gas aus der Biomassevergasung sowie der Betrachtung von Biomassevergasungsanlagen aus dem Blickwinkel Gesundheit, Sicherheit und Umweltverträglichkeit.

Ein detaillierter Überblick über den Stand der Technik der Biomassevergasung in Österreich und den anderen Task Mitgliedsländern wurde erarbeitet. Hier findet man eine Übersicht über sämtliche geplante- und in Betrieb befindliche Biomassevergasungsanlagen aus allen Task Mitgliedsstaaten.

In Task 33 wird international zusammengearbeitet, dadurch ist es im Gegensatz zu EU-Projekten auch möglich, die Erfahrungen von Organisationen aus den USA und Kanada einzubringen. Der Erfahrungsaustausch und die gemeinsamen Aktivitäten in dieser Task sind für Österreich sehr wertvoll, da zurzeit einige Vergasungsprojekte in der Demonstrationsphase sind, in die die Erfahrungen aus Projekten in anderen Ländern auf diesem Wege einfließen können.

Im Triennium 2010-2012 werden die Schwerpunkte von Task 33 in folgenden Bereichen liegen: Synthesegasherstellung aus Biomasse, Produktion von Chemikalien, Vorteile der Kraft-Wärme-Kopplung durch Vergasung, Nachhaltige Entwicklung (Brennstoffe, Wasser, Sozio-ökonomische Vorteile, Versorgungssicherheit).

Summary

The scope of the work for Task 33 is the organization of semi-annual Task Meetings to exchange and review global R&D programs and projects to identify barriers to commercialize biomass gasification process (BMG). Information exchange is used to prepare and update Country Reports and R&D needs and to make them available to national team leaders to support in the development of their respective national BMG and bioenergy plans. Subtask studies include focused technical workshops, with industrial and academic experts to address the key barriers for fostering BMG. Wherever possible, conduct joint studies with related tasks, annexes, and other international activities to pursue mutually beneficial investigations.

In Triennium 2007-2009 were 6 meetings were hold, including a workshop on a defined topic. The Meeting Minutes can be found on homepage www.ieatask33.org.

Austria as a subtask-leader worked on following Task Projects (2007-2009):

- Country Reports
- Analytical methods for characterisation of synthesis gas
- Operating experience of biomass gasifications systems

In addition Austria is active in the projects such as Standards of tar measurement, Biomass gasification for production of hydrogen and hydrogen-rich gas and last but not least Health-, safety- and environmental aspects of biomass gasification plants.

A State of the Art of biomass gasification process is given for Austria and other Task member countries. An overview about gasification plants in member countries, which are in operation and planned, as well as details concerning the biomass gasification plants in Austria was drawn up.

Cooperation in Task 33 is worldwide. This makes possible (by contrast to EU projects) that experiences from USA and Canada are also available. The information exchange and cooperation activities of the Task 33 are very valuable for Austria as a member country, because several commercial and demonstration projects are currently underway. The experiences of projects in other countries can be applied to these projects.

In the triennium 2010-2012 the focus of topics will be especially on: Synthesis gas from Biomass, Biofuels, SNG, Chemicals, and CHP; Co-production; Integration with Lignocellulosic Biorefinery Processes; Sustainability (Feedstock, Water, Greenhouse Gas, Socio-economic Benefits, Security of Supply).

1. Introduction

1.1 IEA Bioenergy Implementing Agreement

Since 1978 Austria is member of the Bioenergy Implementing Agreement of the International Energy Agency (IEA Bioenergy). The participation in the various Tasks is financed by the Federal Ministry for Transport, Innovation and Technology (BMVIT). Several Austrian research institutions participate in Tasks with a common working period of 3 years. The recent period lasted from 1.1.2007 to 31.12.2009.

„The Bioenergy Implementing Agreement“ of International Energy Agency (version of 13.10.2005) is the formal basis for IEA Bioenergy. „The Strategic plan 2003-2006“ describes the principles of IEA Bioenergy. Detailed information about the principles is available on the IEA Bioenergy website (http://www.ieabioenergy.com). The Executive Committee (ExCo) is made up of one representative from each participating country and from the European Commission (at present 22 participants). The Austrian representatives are J. Spitzer (member) and M. Ammer (alternate member). The office is led by J. Tustin (New Zealand). General information about the work of IEA Bioenergy is provided e.g. „IEA Bioenergy newsletters“ and „Annual Reports“. Publications and Reports are available on the IEA Bioenergy website (see chapter 7: Know-how Transfer).

1.2 IEA Bioenergy Task 33 “Thermal Gasification of Biomass”

The IEA Bioenergy Task 33 – “Thermal Gasification of Biomass” offers a forum for National Team Leaders (NTLS) to exchange, review, and evaluates information from worldwide biomass gasification (BMG) RD&D programs and operating commercial and pilot plants that should assist in the development of national bioenergy programs and to advance the state-of-the art of BMG. In recognition of the potential to produce fuels and chemicals via synthesis gas the Task expands its role to address issues related to synthesis gas in addition to combined heat and power (CHP) and power. The Task continues its interaction with industrial and academic experts to coordinate technology and product development. A new initiative involves cooperation with ‘policy’ related tasks to address critical issues along the entire value chain from feedstock to market deployment of gasification based bioenergy products. These activities are very useful for participating countries to refine national bioenergy plans as well as to explore cooperative RD&D projects with other National Team Leaders.

The Task objectives are:

- Conduct subtask studies to review and evaluate information from the current worldwide RD&D programs and operating gasification systems to identify and resolve barriers for advancement of economical, efficient, and environmentally preferable BMG processes.

- Promote commercialization of BMG to produce fuel and synthesis gases that could be subsequently converted to substitutes for fossil fuel based energy products and chemicals and lay the foundation for secure and sustainable energy supply.
- Enable NTLS to develop forward looking strategies and policies to implement programs in their respective countries, and help ‘leapfrog’ resource consuming repetitive and redundant exercises.

Work Scope:

Organize semi-annual Task Meetings to exchange and review global RD&D programs and projects to identify barriers to commercialize BMG. Use the survey information to prepare and update Country Reports and RD&D needs and to make them available to NTLS to support in the development of their respective national BMG and bioenergy plans. Conduct subtask studies including focused technical workshops, with industrial and academic experts to address the key barriers to advancing BMG. Wherever possible, conduct joint studies with related tasks, annexes, and other international activities to pursue mutually beneficial investigations.

Austria as a subtask-leader worked on following Task Projects (2007-2009):

- Analytical methods for characterization of synthesis gas (see chapter 6)
- Operating experience of biomass gasification systems (see chapter 6)

In addition Austria is active in the following projects:

- Country Reports (see chapter 4 and 5.)
- Health-, safety- and environmental aspects of biomass gasification plants (see chapter 6)

2. Gasification

2.1 Gasification introduction

Gasification is the complete thermal breakdown of the biomass particles into a combustible gas, volatiles and ash in an enclosed reactor (gasifier) in the presence of any externally supplied oxidizing agent (air, O2, H2O, CO2, etc.) when equivalent ratio (ER) is < 1.

ER = 1 if the stoichiometric amount of oxidising agent is present. Stoichiometric amount is the theoretical amount of air or any other oxidizing agent required to burn the fuel completely.

Gasification is an intermediate step between pyrolysis and combustion.

Gasification is a two-step, endothermic process. During the first step the volatile components of the fuel are vaporized at temperatures below 600°C by a set of complex reactions. No oxygen is needed in this phase of the process.

Hydrocarbon gases, hydrogen, carbon monoxide, carbon dioxide, tar and water vapour are included in the volatile vapours. Char (fixed carbon) and ash are the by-products of the process which are not vaporized. In the second step, char is gasified through the reactions with oxygen, steam and hydrogen. Some of the unburned char is combusted to release the heat needed for the endothermic gasification reactions.

Main gasification products are gas, char, and tars. Gasification products, their composition and amount are strongly influenced by gasification agent, temperature, pressure, heating rate and fuel characteristics (composition, water content, granulometry). Gaseous products formed during the gasification may be further used for heating or electricity production. The main gas components are CO, CO_2, H_2O, H_2, CH_4 and other hydrocarbons.

Combustible gas, produced during gasification can be cleaned and used for the synthesis of special chemical products or for the generation of heat and/or electricity. Specific hydrogen – carbon monoxide mixtures (because of the production method or the final use) have the designation water gas, cracked gas, and methanol synthesis gas or oxo-synthesis gas.

The fundamental reactions of the synthesis gas chemistry are the methanol synthesis, Fischer–Tropsch (FT) synthesis, oxo-synthesis (hydroformylation) and methane synthesis; further synthesis gas reactions are being developed.

Gasification has the unique characteristic of being such a technology that can even convert waste (from MSW to agricultural or crop residues, like coconut shells, rice husks, straw, wood residues, bagasse, etc.) to a useful and high quality energy source. It is known how complicated the disposal of any kind of waste is, nowadays due to environmental regulations and legislations. Gasification gives the advantage of separating the noxious substances from the fuel gas prior to the combustion.

2.2 Gasification technologies

Gasification process takes place in a conversion unit usually called gasifier. There are several types of gasifiers (see Figure 1, page 4 and Table 1, page 5).

Gasifiers can be classified:

- according to the oxidant

- air-blown gasifiers
- oxygen/steam gasifiers

- according to the heat supply for gasification:
  - autothermal gasifiers
  - allothermal gasifiers

- according to the design of fuel bed:
  - fixed bed gasifiers
  - fluidized bed gasifiers
  - entrained flow gasifiers

- according to pressure:
  - atmospheric gasifiers
  - pressurized gasifiers

- according to the fuel gas end use:
  - heat gasifiers
  - power gasifiers

Heat gasifiers are used to power external burners in boilers, kilns or dryers. Power gasifiers are coupled to the internal combustion engines or gas turbines for shaft power producing.

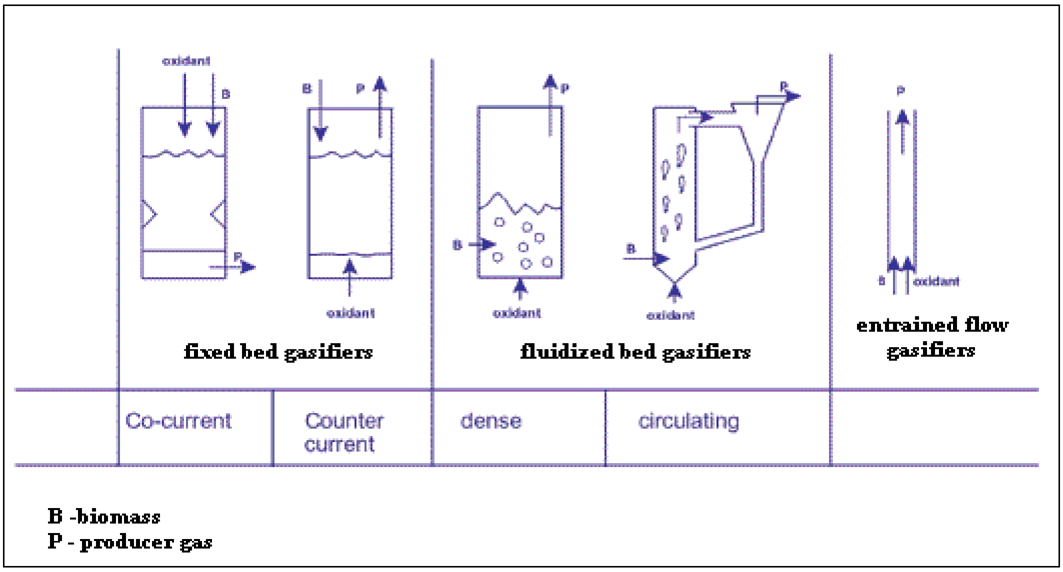

Figure 1: Different types of gasifiers

Table 1: Classification of biomass gasifiers

Classification	Type	Mode of contact
Dense phase reactors - Fix bed gasifier	Updraft	Solid moves down, gas moves up
	Downdraft	Solid moves down, gas moves down
	Cocurrent	Both solid and gas move in the same direction
	Countercurrent	Solid and gas move in opposite directions
	Crosscurrent	Solid moves down, gas moves at right angles
	Variations	Stirred bed; Two stage gasifier
	Moving bed	Mechanical transport of solid. Low temperature processes. Includes: multiple hearth, horizontal moving bed, sloping hearth, and screw/auger kiln.
Lean Phase reactors - fluidized-bed gasifier and entrained-bed gasifier	Bubbling fluidized-bed	Low gas velocity, inert solid stays in reactor.
	Fast fluidized-bed	Inert solid is elutriated with product gas and recycled.
	Circulating fluidized-bed	Inert solid is elutriated, seperated, and recirculated. This sometimes also refers to fast fluidized-bed or twin reactor system.
	Entrained flow bed	Usually no inert solid. Highest gas velocity, can be operated as a cyclonic reactor.
	Twin fluidized-bed	Steam gasification and /or pyrolysis occur in the first reactor. Char is combusted in the second reactor to heat the fluidising medium for recirculation. Either can be any type of fluidized-bed, although the combustor is often a bubbling fluidized-bed.

The composition of the gas and the level of undesirable components (tars, dust, ash content) produced during biomass gasification process are dependent on many factors such as feedstock composition, reactor type and operating parameters (temperature etc; Table 2, page 6).

Typical composition of a dry gas produced during the biomass gasification process is shown in table 3, page 6. As can be seen, the concentration of the gas compounds during air and steam gasification is completely different.

Table 2: Typical gasifier characteristics (Bridgwater, 1995)

	Temperature [°C]					**MW_{el}**	
	Reaction	**Exit gas**	**Tars**	**Particu-lates**	**Scale-up ability**	**min**	**max**
Downdraft	1000	800	very low	moderate	poor	0.1	1
Updraft	1000	250	very high	moderate	good	1	10
Stationary fluidized bed	850	800	medium	high	good	1	20
Circulating fluidized bed	850	850	low	very high	very good	2	100
Entrained flow	1200	1000	low	very high	good	5	500

Table 3: Typical composition of a dry product gas during the biomass gasification and Low Heating Value (LHV)

Compound		**Air gasification**	**Steam gasification**
CO	Vol. %	10-15	20-25
CO_2	Vol. %	10-15	20-25
H_2	Vol. %	15-20	30-40
CH_4	Vol. %	3-5	6-12
N_2	Vol. %	45-55	1-5
LHV	MJ/Nm^3	4-6	10-14

During the air gasification, air is used as a fluidizing agent (air contains about 78 vol.-% of nitrogen), that is why the nitrogen concentration in the product gas is very high contrary to steam gasification. Nitrogen in the product gas during the steam gasification originates from the fuel and its concentration is low.

On the other hand the higher amount of hydrogen in the product gas can be found during the steam gasification. The hydrogen found in the product gas does not originate only from the fuel as in the case of air gasification but also from the steam (H_2O).

3. Advantages and Disadvantages of Biomass Gasification

Biomass is the leading source of renewable energy in many countries. At present, biomass contributes approximately 14% of primary global energy while using only about two-fifths of the existing biomass energy resources. Hence, the potential exists for increasing biomass utilization for subsequent conversion to renewable fuels and chemicals, and renewable power. In many countries the current biomass use is clearly below the available potential but the situation is different in Asia, where the current use exceeds supply. To promote commercialization of biofuels, chemicals, and power, a robust incentive driven infrastructure for sustainable supply of biomass should be developed, particularly in Asian countries and other equatorial regions. It is conceivable that the strategy to develop this infrastructure could be deployed as an integral part of tangible actions to reduce GHG (Greenhouse Gas) emissions and promote economic growth in non-OECD countries.

The following are some measures to initiate this mission:

- Increased utilization of forest residues and residues from wood processing, sugar production, and oil palm biomass
- Collection and utilization of all agricultural residues
- Co-processing of agricultural, urban and industrial wastes
- Utilization of municipal and industrial waste waters to develop energy plantations
- Legislating policies and incentives that would engage rural and farming communities in the growth, management, harvesting, and supply of biomass on a large scale

As explained on the beginning, combustion converts biomass essentially into heat, CO_2 and H_2O, gasification operating under sub-stoichiometric conditions produces heat, a fuel or synthesis gas with CO, H_2, CH_4, other light and condensable hydrocarbons. Gasification temperatures being lower than combustion, the problems with slagging, fouling, and corrosion caused by alkali and chlorine compounds are eliminated. Under the reducing environment in a gasifier any N or S in biomass is converted to NH_3 and H_2S which could be removed at a lower cost compared to NO_x and SO_x produced in combustion. Gasification products could be used for producing fuels, chemicals, and high-efficiency and clean power, much more than what combustion provides. Other benefits of gasification over combustion include the low volume of gases to handle and the ability to economically separate and capture CO_2.

The merits of gasification are well established with fossil fuels. The technology developed for gasification of coal is mature and its application to produce efficient IGCC (Integrated Gasification Combined Cycle) power, fertilizers, SNG (Synthetic Natural Gas), and liquid fuels has been proven commercially. Many aspects of these technologies are now applied with significant economic benefits for processing other fossil fuels and they would be applicable for biomass gasification. The environmental benefits of biomass are illustrated in figure 2. Figure 2 shows the relationship between GHG (Greenhouse gas) emissions to production of alternative fuels and chemicals. It is apparent that biomass gasification, compared to other bioenergy conversion processes would be the principal technology to produce most of the low emission fuels such as FT diesel, SNG, and methanol.

It is conceivable that with increasing emphasis on search for fungible substitutes for fossil fuel derived products, bio-refineries could evolve, similar but on a different scale of operation to the Shell Middle Distillate Synthesis (SMDS) co-production facility in Bintulu, Malaysia, with the ability to respond to rapidly changing market demand for fuels and chemicals. Figure 3 illustrates a general schematic of a bio-refinery incorporating the leading biomass energy conversion pathways to co-produce fuels, chemicals, and power.

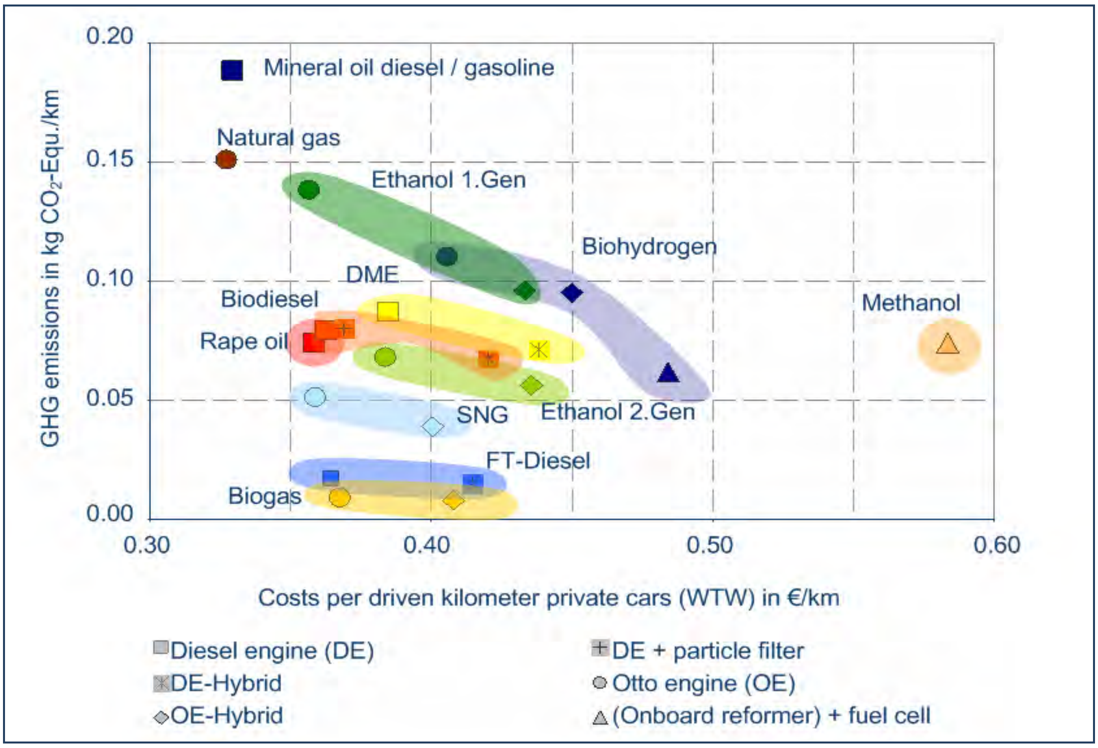

Figure 2: Comparison of technologies: economic versus environmental aspects

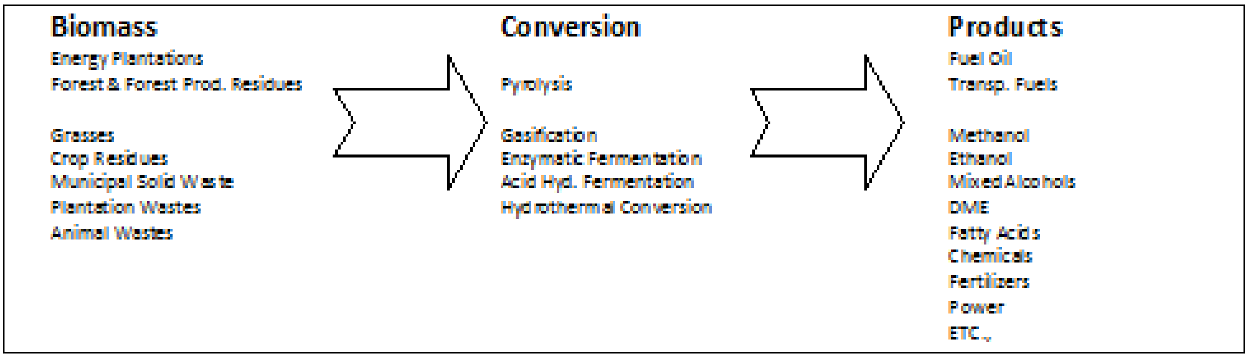

Figure 3: General illustration of a biorefinery

As stated above, gasification could quantitatively convert most types of heterogeneous biomass into a uniform in composition fuel gas or synthesis gas that could be converted into a single product or a mix of co-products shown above. Other biomass conversion processes may require several simultaneous, sequential, and integration of processing steps to produce the same product(s). The inherent advantage of gasification followed by single-pass synthesis gas conversion to co-produce fuels and chemicals and producing green power from unconverted gases presents another yet to be commercially explored opportunity for biomass gasification.

4. Biomass Gasification – State of the Art

4.1 Biomass Gasification worldwide

In the country reports of IEA Bioenergy Task 33 there is given a very good overview about recent developments. The individual country reports of the participating countries are available at the homepage of the task (http://www.gastechnology.org/webroot/app/xn/xd.aspx?it=enweb&xd=iea/countries.xml).

Of the various biomass gasification processes, the following deserve recognition, for their successful operation, ability to compete with conventional fuels at their host sites, and for their innovative contributions to advance the technology. These processes can be divided by the usage of the gas and the operation status: Gasifiers in operation (on commercial basis), Table 4; Gasifiers planned or under construction / commissioning, Table 5, page 11, and R&D gasification systems, Table 6, page 12.

Table 4: Gasifiers in operation (on commercial basis)

Technology / Supplier	**Gasification agent**	**Type of reactor**	**Location**	**Gas usage**
Lurgi/ Zement CFBG gasifying	air	CFB	Rüdersdorf, Germany	Gasification of RDF to fire cement kiln
Lurgi/Essent	air	CFB	Geertruidenberg, The Netherlands	co-firing in a PC boiler
Foster Wheeler	air	CFB	Lahti, Finland	co-firing
Foster Wheeler	air	CFB	Ruien, Belgium	co-firing
Foster Wheeler	air	CFB	Norrsundet, Sweden	lime kiln gasifier
Foster Wheeler	air	CFB	Karlsborg, Sweden	lime kiln gasifier
Foster Wheeler	air	CFB	Rodao, Portugal	lime kiln gasifier,

Table 4: Gasifiers in operation (on commercial basis) cont.

Technology / Supplier	**Gasification agent**	**Type of reactor**	**Location**	**Gas usage**
Foster Wheeler	air	BFB	Varkaus, Finland	gasifier for aluminum recycling and co-firing
Götaverken/ Metso Power	air	CFB	Värö Sweden	lime kiln gasifier
FICFB / Repotec	steam	Dual fluidized bed	Güssing (A)	CHP, R&D for syngas applications
FICFB / Ortner	steam	Dual fluidized bed	Oberwart (A)	CHP, R&D for syngas applications
Babcock & Wilcox Vølund	air	updraft gasifier	Harboøre, Denmark	CHP
Babcock & Wilcox Vølund	air	updraft gasifier	Yamagata and Kani City, Japan	CHP
Nexterra thermal gasifiers in and University of South Carolina , USA	air	moving bed	Tolko Heffley Creek Mill, Dockside Green, and Kruger products in Canada	heat
Pyroforce/CTU	air	downdraft	Spiez and Nidwalden, Switzerland	CHP
Biomass Engineering Ltd.	air	downdraft	Cumbria, UK and Dortmund, Wildhausen, Germany	CHP
Bioneer/Jalasjärvi	air	updraft	More than 10 in Finland and Sweden	district heating
PRM	air	updraft	Rossano, Italy	Heat for steam cycle
PRM	air	updraft	10 in US, Australia & Malaysia	thermal application plants
Community Power	air	downdraft	18 in USA	CHP
Carbona	air	BFB	Skive, Denmark	CHP

Definitions Type of reactor, see Table 1, page 5.

CFB … Circulating fluidized-bed , BFB … Bubbling fluidized-bed

Table 5: Gasifiers planned or under construction / commissioning

Technology	Gasification agent	Type of reactor	Location	Gas usage
Carbo V	oxygen	Staged gasification	Freiberg (Germany)	FT fuels
Bioliq	oxygen	Entrained flow with decentral pyrolysis	Karlsruhe (Germany)	Methanol and gasoline
AER	steam	Dual fluidized bed	Geislingen (Germany)	CHP, R&D for syngas applications
Heat Pipe Reformer	steam	Indirect heated BFB	Pfaffenhofen (Germany)	CHP, R&D for BioSNG
BioMCN	oxygen	Entrained flow	The Netherlands	Methanol
Enerkem	oxygen / steam	BFB	Canada	Ethanol
Range Fuels		Staged gasification	USA	Ethanol
GoBiGas	steam	Dual fluidized bed	Göteborg, Sweden	BioSNG
Metso Power	air	CFB	Lahti Finland	160 MW_{fuel} CHP
FICFB / Repotec	steam	Dual fluidized bed	Ulm (Germany)	CHP
FICFB / Ortner	steam	Dual fluidized bed	Villach (Austria)	CHP

Definitions Type of reactor, see Table 1, page 5.
Staged gasification … gasification in more than one stage
Dual fluidized bed or Twin fluidized bed

Table 6: R&D gasification systems

Technology	**Gasification agent**	**Type of reactor**	**Location**	**Gas usage**
Artfuel	oxygen / steam	CFB	Clausthal (Germany)	FT fuels
MILENA	steam	Dual fluidized bed	ECN, (The Netherlands)	BioSNG
Chemrec	oxygen	Entrained flow	Piteo, Sweden	DME
Chrisgas	oxygen / steam	CFB	Värnamo, Sweden	Synthesis gas
GTI	oxygen / steam	BFB	Chicago, USA	FT fuels
Ultra Clean Gas / VTT, Neste Oil, Stora Enso	oxygen / steam	CFB	Finnland	FT fuels

Definitions Type of reactor, see Table 1, page 5.

Recent innovations in process integration have shown that it is technically possible to retrofit a bubbling or circulating fluidized bed biomass gasifier with existing circulating fluidized bed biomass combustors (CFBC) as shown below in Figure 4, under development at Chalmers University of Technology, Sweden. Taking advantage of this concept where possible with the nearly existing 600 CFBC units should help advance the case for biomass gasification.

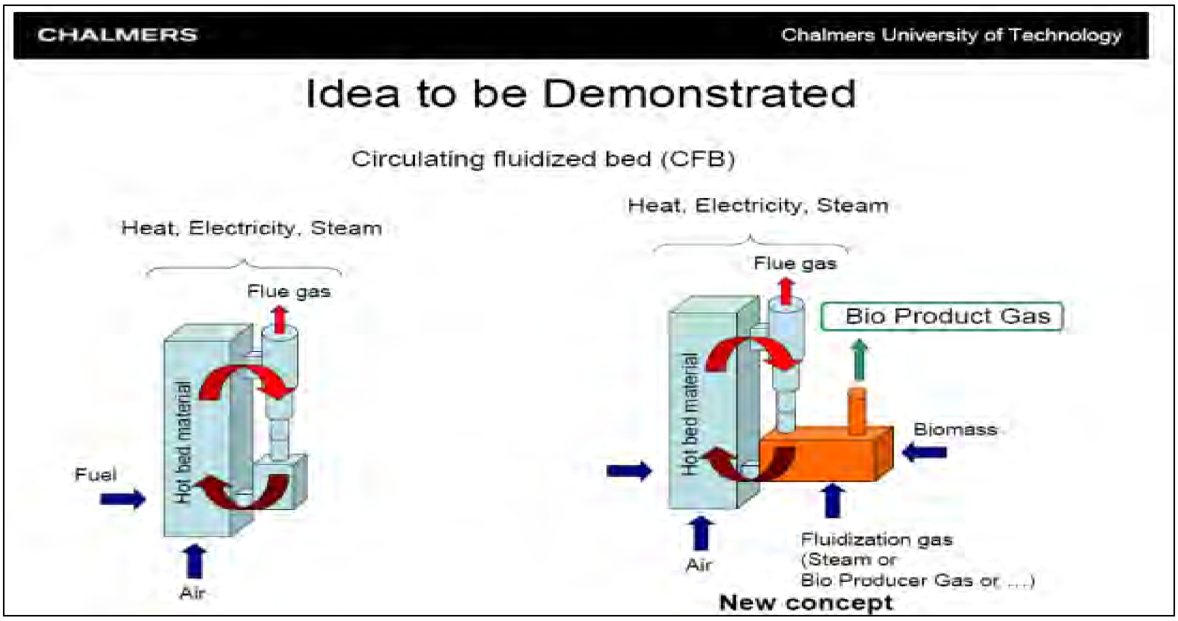

Figure 4: Retrofit installation of a biomass gasifier (in red) at existing CFBC plants

Biomass gasifiers have been successfully employed in forest products industries for several decades to fire lime kilns with attractive pay back. The existing infrastructure in forest products industries including delivery, storage, handling, size reduction, and wood fractionation, ash and waste water disposal, provide other site-specific innovative retrofit options for installing biomass gasification to expand operations and range of products. Such retrofits can readily displace the use of fossil fuels, to generate the entire plant parasitic utility requirements and even generate exportable surplus power. Furthermore, the successful deployment of black liquor gasification technology, such as the one developed by Chemrec in Sweden, in a forest products industry will result in valuable byproduct credits by co-production and marketing of chemicals and fuels.

Combined heat-power applications, co-firing and production of synthesis gas are the three most widely used applications for biomass gasification.

Biomass gasification for CHP (combined heat-power) applications

Combined heat and power systems are very useful systems, in which biomass is used to generate power, and heat is created as a byproduct of the power generation system. They have a very high cost because of the high pressure operation. Because of this high pressure operation, the need for a highly trained operator is mandatory, and will raise the cost of operation. Another drawback is that while they produce electricity they will produce heat, and if producing heat is not desirable for certain parts of the year, the addition of a cooling tower is necessary, and will also raise the cost.

The gasification plant in Güssing is an example of CHP applications. The developmental aim is for a current-led heat power combination with high electrical efficiency for larger capacity applications. Due to the favorable characteristics of the product gas (low nitrogen, high hydrogen content) there are several research projects, which use slip streams of the product gas. Details concerning the plant in Güssing can be found in 4.1.1.

Co-firing

Biomass is sometimes co-fired in existing coal plants instead of new biomass plants. Co-firing can also be used to improve the combustion of fuels with low energy content. Co-firing can be used to lower the emission of some pollutants. For example, co-firing biomass with coal results in less sulfur emissions than burning only coal.

The gasification plant in Lahti, Finland can be a good example of co-firing technology. Since 1998, Lahti Energy has gasified over million tons of solid recovered fuels and wood and used the producer gas in a coal power plant. This reduced the use of coal by over 600 000 tons

Synthesis gas

Syngas (from *synthesis gas*) is the name given to a gas mixture that contains varying amounts of carbon monoxide and hydrogen. Examples of production methods include steam reforming of natural gas or liquid hydrocarbons to produce hydrogen, the gasification of coal, biomass, and in some types of waste-to-energy gasification facilities. The name comes from their use as intermediates in creating synthetic natural gas (SNG) and for producing ammonia or methanol**.** Syngas is also used as an intermediate in producing synthetic petroleum for use as a fuel or lubricant via the Fischer–Tropsch process and previously the Mobil methanol to gasoline process.

Syngas consists primarily of hydrogen**,** carbon monoxide, and very often some carbon dioxide**,** and has less than half the energy density of natural gas. Syngas is combustible and often used as a fuel source or as an intermediate for the production of other chemicals.

4.2 Biomass Gasification in Austria

Projects:
Graz University of Technology – Institute of Thermal Engineering
http://portal.tugraz.at/portal/page/portal/TU_Graz/Einrichtungen/Institute/Homepages/i3070/forschung/AG_Energiesysteme_Biomassenutzung bzw. www.iwt.tugraz.at

- Evaluation and optimization of a fixed bed gasifier, gas cleaning system and gas engine
- R&D of a two staged gasification system
- Health, Safety and environmental issues for gasification systems

Joanneum Research Graz, RESOURCES - Institute for Water, Energy and Sustainability, Energy Research
http://www.joanneum.at/resources/eng.html

- Life Cycle Assessments
- Scientific Partner in Bioenergy 2020+

Vienna University of Technology, Institute of Chemical Engineering
http://www.vt.tuwien.ac.at/ bzw. http://www.vt.tuwien.ac.at/division/division.php?div=4

- R&D in dual fluidized bed steam gasification
- Production of Fischer Tropsch fuels
- Production of BioSNG
- Production of mixed Alcohols
- Production of hydrogen
- Usage of the product gas in fuel cells
- Scientific Partner in Bioenergy 2020+

Bioenergy 2020+
http://www.bioenergy2020.eu/content/competence_areas/thermal_gasification

- Pressurised gasification (in cooperation with Vienna University of Technology)
- Usage of product gas from Steam gasification in a SOFC
- Production of FT liquids (in cooperation with Vienna University of Technology)
- Production of mixed alcohols (in cooperation with Vienna University of Technology)
- Production of hydrogen (in cooperation with Vienna University of Technology)
- Waste gasification

MCI – University of Applied Sciences for Environmental-, Process- and Biotechnology, Innsbruck
http://www.mci.edu/de/studium/bachelor/umwelt-verfahrens-energietechnik/energietechnik/forschung-entwicklung

- Multi-staged fixed bed gasification systems
- Gas cleaning for CHP applications

FJ-BLT Wieselburg (HBLFA)
http://blt.josephinum.at/index.php?id=640

- Biomass availability
- 1st and 2nd generation biofuels

4.2.1 BIOMASSEKRAFTWERK GÜSSING GMBH & CO KG

In Guessing a Biomass CHP with the concept of the FICFB gasification system was realized (detailed data Table 7, page 16).

The basic idea of the FICFB concept (http://www.ficfb.at/) is to divide the fluidized bed into two zones, a gasification zone and a combustion zone. Between these two zones a circulation loop of bed material is created but the gases should remain separated. The circulating bed material acts as heat carrier from the combustion to the gasification zone. The fuel is fed into the gasification zone and gasified with steam. The gas produced in this zone is therefore nearly free of nitrogen. The bed material, together with some charcoal, circulates to the combustion zone. This zone is fluidized with air and the charcoal is burned.

The exothermic reaction in the combustion zone provides the energy for the endothermic gasification with steam. With this concept it is possible to get a high-grade product gas without the use of pure oxygen.
The construction of the demonstration plant started in July 2000 and it started operation in November 2001. After first tests of the gasifier, the gas engine was started in April 2002. Detailed data can be found below. With this demonstration plant the scale up of the FICFB gasification process was realized and now the R&D on the gasifier and all ancillary units is going on, that the turn key contractor Repotec can bring an economical and commercially viable biomass driven power station to the market.

The developmental aim is for a current-led heat power combination with high electrical efficiency for larger capacity applications. Due to the favorable characteristics of the product gas (low nitrogen, high hydrogen content) there are several research projects, which use slip streams of the product gas.

The most important are:
- production of Fischer Tropsch Diesel
- production of Methane (synthetic natural gas)
- usage the gas in a SOFC
- catalytic cracking of the tars

Table 7: Detailed data Güssing

Owner:	Biomassekraftwerk Güssing GmbH & CO KG
Constructed by	Austrian Energy / Repotec
Power production	2000 kW
Heat production	4500 kW
Biomass type used	Wood chips
Start up	November 2001
Hours of operation (gas engine) by end of December 2009:	43,400

4.2.2 ENERGIE OBERWART GMBH & CO KG

In Oberwart (detailed data Table 8) the second Biomass CHP with the concept of the FICFB gasification system was realized.

It consists similar to the biomass CHP Güssing of gas generation in a DFB (Dual fluidized bed) system, gas cooling and gas clean-up in a bag filter followed by a tar scrubber. The cooled and cleaned producer gas is fed into two gas engines for power generation. In addition there is a biomass drying unit and an organic rankine cycle (ORC) integrated, to have a higher electric efficiency. For the ORC all heat at the biomass CHP is collected by thermo-oil and transferred in the ORC in electricity.

The construction was completed in December 2007 and since 2008 is in operation.

Table 8: Detailed data Oberwart

Owner:	Energie Oberwart GmbH
Constructed by	Ortner Anlagenbau
Power production	2750 kW
Heat production	1500-6000 kW
Biomass type used	Wood chips
Status:	In operation

5. Advances in Biomass Gasification Processes

The last decade has seen a revival of interest in biomass gasification driven primarily by interest in biofuels to help with energy supply and to reduce the use of fossil fuels. The following descriptions are condensed outputs of the Country Reports (details http://www.gastechnology.org/webroot/app/xn/xd.aspx?it=enweb&xd=iea/countries.xml).

TUV-FICFB: In this regard the indirectly heated biomass gasifiers such as the TUV-FICFB or Silvagas processes producing a N_2-free medium calorific value synthesis gas without the use of oxygen have drawn considerable attention. During the last six years, the 8 MW_{th}, TUV-FICFB demonstration plant at Güssing has logged-in more than 40,000 hours of operation. The operational reliability of this plant has transformed the CHP plant into a test bed for techno-economic evaluation of producing BTL, bio-SNG, hydrogen, and electricity production from high-temperature fuel cells. The recently installed, 1 MW_{th} slipstream bio-SNG plant has also been in successful operation as demonstrated by show casing propulsion of bio-CNG automobiles.

Of the many interesting features of the Güssing plant is its ability to recover sensible heat from the raw gases, removal of entrained particulate matter with fabric filters, and tar removal by scrubbing with RME, and recycling the scrubbed solvent with tars to the gasifier circumventing the need for water scrubbing. Having achieved >90% plant availability, the demonstration plant consistently produces a medium heating value fuel gas with low tar content that is acceptable for generating power using GE Jenbacher gas engines.

The second commercial demonstration of the TUV-FICFB process at Oberwart (~10 MW_{th}, 60 TPD biomass) is operating with >90% availability and with high electrical efficiency (see als 4.1.3). At this facility the electrical efficiency is > 30 % by integrating the gas engine with an organic Rankine cycle (ORC) heat recovery and utilization system. Plant operations have been improved to produce ash with <0.5% carbon, H_2/CO ratio of 1.5 to 2, condensate or waste-water-free operations, and compliance with European emission requirements.

Tests with mixed wood and straw in the TUV-FICFB process showed that no problems were encountered in handling up to 15% by weight straw, as long as the ash fusion temperature is above 1000 ^{o}C. The plant was also able to co-gasify saw dust, wood & sludge pellets, and coal. The existing gas purification system of scrubbing with RME, fabric filters and adsorbens were able to remove H_2S, mercaptans, thiophenes, HCl, NH_3, and dust for slip-stream studies to evaluate the conversion of raw gas into H_2, mixed alcohols, FTL, BioSNG, in addition to producing a fuel gas suitable for solid oxide fuel cells. With progressive improvement in operations at Güssing and Oberwart, the scale-up and commercialization of the TUV-

FICFB should continue to provide useful insights into the design and operation of biomass gasification plants in general.

METSO Power: In reviewing the success of fluidized bed gasifier for over 20 years and that of the indirectly heated TUV-FICFB process, METSO is investigating the retrofit option of an FICFB type of gasifier at existing CFBC plants for bio-SNG applications. Metso's success in cleaning raw gases with 200 ceramic filters at the Sodra Cell Varo paper mill should help in its pursuits to develop bio-SNG and the prospective expansion of the Lahti co-firing operations. Metso is now seriously considering employing the TUV-FICFB biomass gasification system for building a 30 MW_{th} Bio-SNG plant (Gobigas project) in Sweden.

CHOREN: The CHOREN technology under development in Freiberg, Germany is based on the two-stage, 5 bar operating pressure 'Carbo-V' process which involves low temperature gasification of biomass at 400-500°C followed by high-temperature entrained oxygen- blown gasification of the resulting products of devolatilization at above 1400 °C. The char from stage 1 is ground and introduced into the entrained gasifier fed with products of devolatilization at 400-500°C, to accomplish complete gasification at about 800 °C and produce a tar-free synthesis gas, consisting primarily CO and H_2. The partially cooled raw gas at 5 bar is cleaned to remove entrained particles, subjected to water-gas shift for adjusting $CO:H_2$ ratio to 1:2, followed by scrubbing to remove acid-gases, and cleaned further by ultra-gas cleaning to remove chlorine (<10 ppb) and sulfur compounds (<50 ppb). The clean synthesis gas is then compressed to 30 bars for subsequent conversion to produce liquid fuels using the Shell FT synthesis process which is carried-out in a fixed bed of cobalt catalyst. Among the many accomplishments in pursuing process scale-up and demonstration, the following improvements were claimed for the planned 640 MW_{th} Sigma (σ) plant gas conditioning process with that of the 45 MW_{th} β-plant:

- Reduced consumption of chemicals (primarily NaOH) for water wash stages (including HCl removal)
- Lower quantity of concentrated chemicals (ex. NaCl) to dispose
- Use of a single gas compressor (lower CAPEX) for producing 30 bar gas for conditioning and synthesis
- Use of physical absorption solvents for CO_2 and H_2S removal followed by sulfur recovery to reduce CAPEX
- Addition of hot N_2 regeneration to strip and produce H_2S-free solvent – to lower CAPEX (Capital costs) and OPEX (Operation costs)

bioliq®: The two-stage bioliq® process demonstration at KIT/FZK, Karlsruhe, involves a 2 MW_{th}, biomass capacity twin-screw Air Liquide/Lurgi pyrolysis (in commissioning) followed by entrained, oxygen-blown slagging gasification (in planning) of the char-containing pyrolysis slurry (in a reactor with membrane wall designed by Lurgi) at about 70 bar and 1300-1400 °C. At these operating conditions, the gas is free of tar & dust and ready for conditioning and synthesis to produce

MeOH (Methanol) and higher alcohols, DME (Dimethyl ether), MeOH-to-Olefins (MTO), DME-to-Olefins (DTO), MeOH-to-Gasoline (MTG), and MeOH-to-Synfuels (MTS), or FT (Fischer-Tropsch) liquid fuels. Process improvements involve the addition of sorbents such as trona to remove raw gas contaminants followed by ceramic membrane filters and the use of activated Pt for hydrogenation of any residual naphthalene.

Andritz Carbona: The Andritz Carbona is now demonstrating gasification of biomass pellets in a bubbling fluidized bed of dolomite. Wood pellets are fed through two lock hopper systems into the lower section of the gasifier's fluidized bed. In a bubbling fluidized bed of dolomite, with air at 3 bar pressure and 850 °C at the 28 MW_{th} biomass capacity Skive Fjernvarme I/S, in Denmark district heating plant. This plant is also being utilized as a test bed to evaluate advanced hot gas cleaning concepts. The on-going hot gas clean-up investigated the use of VTT's novel catalytic monolith in a packed bed to reform the tar compounds. The packed bed of catalysts was operated @ 850 to 930 °C and used steam/nitrogen for pulse cleaning. Although, the operation of gas clean-up with periodic pulse cleaning was satisfactory, the performance was poor with 50-70% and <20% reforming of tars and ammonia respectively. Recent efforts involving the participation of Haldor Topsøe A/S (H-T) provided the opportunity to test H-T's proprietary catalysts which demonstrated about 97% tar and 95% of CH_4 decomposition, with low build-up of pressure drop across the hot-gas conditioning reactors. Further investigations showed that the H-T catalysts are effective for NH_3 decomposition, as illustrated in Figure 5. The interesting aspect of this investigation is the impact of H_2S on NH_3 (ammonia) decomposition and reversibility of performance of this proprietary sulfur resistant NH_3 decomposition catalyst.

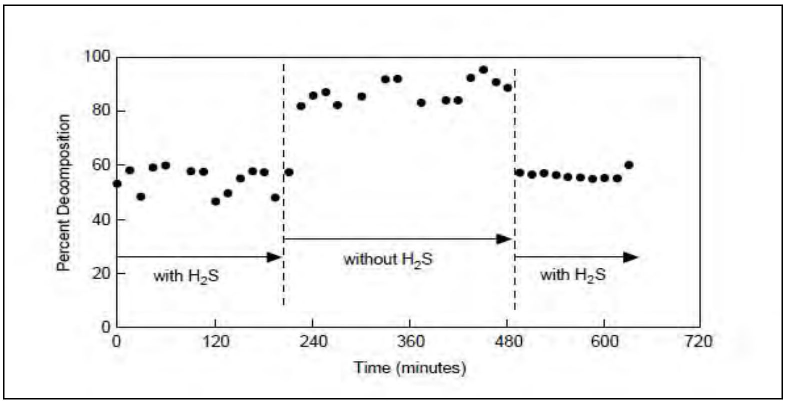

Figure 5: Effect of H_2S on ammonia decomposition (showing reversibility of deactivation)

TIGas Process: In addition to the catalytic investigations with Andritz Carbona, H-T has been developing the Topsøe Integrated Gasoline Synthesis or TIGas Process (Figure 6, page 20) which utilizes air blown gasification of biomass to co-produce fuels and power. H-T claims that this is an effective, simple, moderate pressure, and single-stage catalytic (up to 95%) synthesis gas conversion to MeOH process. The process employs synthesis gas with approximately equal volumes of CO and H_2, in the presence of ~40% N_2, to produce fuels, chemicals, and power.

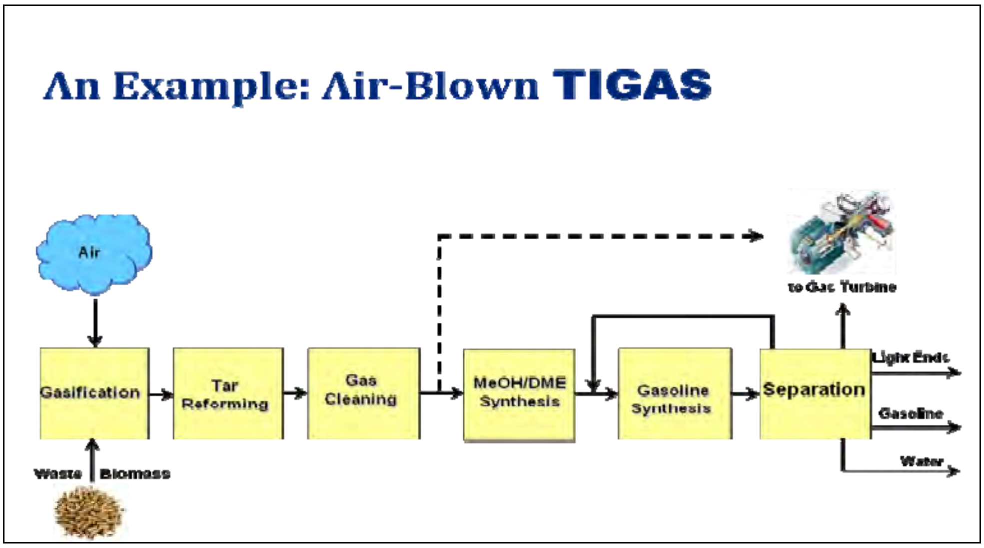

Figure 6: H-T (Haldor Topsøe A/S) TIGas Process

MeOH in turn could be dehydrated to produce DME and it can also be converted to EtOH or gasoline with high product selectivity. The process is described as ".. an improved version of the methanol-to-gasoline process, …converting synthesis gas into gasoline in a single-loop process, thus eliminating the requirement for upstream methanol production and intermediate storage. A brief comparison of the overall process performance with an indirectly heated gasifier (Table 9) shows that the combined efficiency for the TIGas process is slightly less than the TUV-FICFB process. A single-stage air-blown TIGas biomass gasifier would be less costly and easier to operate compared to a multi-stage gasification system.

Table 9: Calculated efficiencies of BMG Fuels and Power Processes based on LHV of Product Gas from Two Gasification Processes

Gasifier Type	Direct Air Gasification	Indirect Gasification
Gasoline %	33.2	50.1
Net Power %	33.9	18.3
Total Effiiciency %	67.1	68.4

The TIGas process requires low gas recycle in the synthesis gas conversion process step, and conserves parasitic energy consumption by circumventing methanol condensation and re-evaporation. The process will incorporate variations of the catalytic gas conditioning schemes mentioned above. A 1 TPD, N_2 containing synthesis gas conversion demonstration plant is now in operation for more than10,000 hours at the H-T facility in Houston, TX, USA. More details could be obtained at www.topsoe.com. In presenting the calculated overall process performance efficiencies, H-T claims that "… combined gasoline and power production seem promising … with air blown pressurised gasifiers with efficient tar reforming and ammonia decomposition catalysts and reformers ..."

CO-GASIFICATION: The discussion on biomass gasification should also recognize the pioneering commercial scale co-gasification efforts at the Vattenfall NUON and the Elcogas Puertallano pressurized Shell coal gasification based IGCC plants. Co-gasification could provide the high-throughput option necessary to reduce cost of operations etc., A brief description of the co-gasification efforts at these sites is summarized below:

Vattenfall NUON (Shell Gasification), Buggenum, Netherlands: The test program of co-gasification of biomass with coal was started in 2001 at the 253 MW_{el} Buggenum Shell coal gasification IGCC plant (electrical eff of 43.1% efficiency) which has the capacity to process about 500,000 t/y coal. The co-gasification test campaign included 34 types of biomass, including wood, chicken litter, municipal sewage sludge, grape seed, palm-pits, cacao meal, sunflower pits etc. Although on a continuous basis, co-gasification of coal with 30% by weight of biomass has been proven, it was necessary to limit biomass to 10% to maintain the required power output. In addition to the biomass materials, 5 types of secondary fuels, such as Pet-cokes, carbon black, Rofire® (paper/plastic residue, residue from paper mills), lignite, and anode dust were also tested. Given the success, particularly with biomass, NUON plans to use biomass as co-feed stocks in the 1300 MW_{el} Magnum IGCC plant which will employ three trains of 2000 tons/day Shell gasification plants.

Elcogas (Shell gasification) Puertallano, Spain: The 100 TPH coal based IGCC Elcogas' Puertallano (Shell gasification) plant has conducted co-gasification with up to 10% by weight of biomass (olive wastes, almond shells, waste wood, vine yard & grape wastes) for over 1130 hours. Besides biomass, the plant has also gasified slaughterhouse wastes. About 2% limestone is added with the feed to capture chlorine and avoid any high-temperature chemical corrosion. The plant has a dedicated biomass feed preparation system. The steam to carbon ratio is 0.15 kg/kg and the oxygen consumption to sustain entrained gasification is ~0.72 Nm^3/Kg feed carbon.

6. IEA Task 33 – Scope of Work and Results

The aim of Task 33 „Thermal Gasification of Biomass“ is to exchange information about the production of gases from biomass to produce heat, electricity and fuels. The information exchange focuses on biomass gasification R&D programs, commercial plants, and potential markets. The objective is to remove technical and non-technical barriers for the market introduction of biomass gasification.

The participant countries for the last triennium were Denmark, Germany, Finland, Canada, Italy, New Zealand, Netherlands, Austria, Sweden, Switzerland, USA and the European Commission.

In Triennium 2007-2009 there were 6 meetings hold, including a workshop on a defined topic. Minutes of the meetings and presentations to download: http://www.gastechnology.org/webroot/app/xn/xd.aspx?it=enweb&xd=iea/taskminutes.xml

The first meeting was hold in March 2007 in Brussels, Belgium. At this meeting the future work program for the triennium was further discussed and details of the future workshops were defined. The workshop of this meeting had the topic “Prospects for BMG Technologies in Future Energy Needs”. During this workshop the task members discussed the past developments and possible future prospects for biomass gasification.

The second meeting took place in ECN in the Netherlands in October 2007. Here a workshop with the topic “Synthesis Gas Clean-up and Characterization” was hold. Here gas cleaning technologies and the different technologies to identify and quantify trace components in synthesis gas from biomass were presented.

The third meeting was hold in April 2008 in Vienna. At this meeting results to date, and the future work program for the triennium was discussed. Details of the future workshops were defined. The topic of the workshop at this meeting was “On the Way to Safe and Eco-friendly Biomass Gasification”. This workshop was organised by the EC-project “Gasification Guide”, by GasNet, and by the Task. A guideline for construction firms and operators of biogas plants was published covering health, safety, and environmental aspects.

The fourth meeting was hold in October 2008 in Montreal, Canada. A workshop on the topic “A Case for Thermal Gasification of Biomass“ was organised. Only Task members participated in this workshop, and different aspects of biomass gasification as well as its future possible development in the countries participating in the Task were discussed. The work programme for the next triennium was also defined at this meeting.

The fifth meeting took place in Karlsruhe, Germany in May 2009. Here was also hold a Workshop: “Biomass Derived Raw Gas Clean-up, Gas Conditioning, and Synthesis Gas Conversion”. The possibilities of product gas cleaning, e.g. using of different catalysts were presented and discussed.

The sixth meeting was hold in November 2009 in Breda, Netherland. Workshop on "Operating Experience with Biomass Gasifiers: Research and Technology Development Needs to Improve Gasification Plant Operations" was also hold here. Also this workshop was a great contribution for all members. The successfully operating commercial plants were presented and also the problems occurring during gasification plants operations were discussed.

The information exchange and activities of the Task are very valuable for Austria because several commercial and demonstration projects are currently underway. The experiences of projects in other countries can be applied to these projects.

Scope of Work

The scope of work for the last triennium was built upon the progress made in the past. In previous years, information exchange, selected subtask studies, coordinated RD&D among participating countries, selected plant visits, and industrial involvement at Task meetings have been very effective in:

- evaluating the state-of-the-art of biomass gasification RD&D and to understand the technical and non-technical hurdles to advance the state-of-the-art and commercialization of BMG
- forming strategic partnerships with participating member countries and industries to initiate new RD&D projects
- advising government agencies on matters pertinent to national bioenergy initiatives, and
- undertaking appropriate joint efforts with other selected bioenergy tasks to investigate technologies and technical issues of mutual interest.

Methodology for Performing Work during 2007-2009

The Task collectively selects the topics for subtask studies by organizing technical workshops, at the semi-annual Task meetings. Industrial and academic experts are invited to participate in the workshop with Task members. Each subtask and the associated workshop will have a coordinator supported by a working team of Task members. The presentations and discussion at the workshop constitute the basic information and guidelines for the subtask studies. Reports resulting from these studies will be reviewed by the Task members, revised if necessary, and published to assist and aid private groups and government agencies interested in commercializing BMG. These reports should also be useful for national policy makers to identify the research needs for further development and advancement of BMG.

Selected results from the Work performing during 2007-2009

Austria was involved in the following Task Projects:

- Country Reports
- Analytical methods for characterisation of synthesis gas

– Operating experience of biomass gasification systems
– Health-, safety- and environmental aspects of biomass gasification plants

The most interesting outcome of the **country reports** is given in chapter 4 and 5. There the most promising technologies and also gasification plants in operation/commissioning/planning are described (download http://www.gastechnology.org/webroot/app/xn/xd.aspx?it=enweb&xd=iea/countries.xml).

A second work of the Austrian NTL was to summarize the analytical methods for **characterization of synthesis gas**. There is worldwide much R&D done in the area of production and usage of synthesis gas from biomass gasification. An underestimated, but very important work on this topic is to characterize the synthesis gas and to identify possible impurities. The second task workshop at ECN was focusing on these topics and a very good overview about the different analytical methods for characterization and analyzing the main gas components, but also impurities like tars, sulphur, chlorine or nitrogen compounds was given.

There are several commercial synthesis gas processes. The most important are:

– Ammonia
– Hydrogen
– Methanol
– Formaldehyde
– DME (Dimethyl ether)
– SNG (Synthetic Natural Gas)

In these, catalysts normally have useful lives of 2 – 5 years. The challenge for development of synthesis gas conversion with any new catalyst is the prevention of deactivation. Not only poisons, but also temperature distribution, hot spots, heating up rate, and pre-treatment / reduction can reduce the lifetime of a catalyst.

The most important poisons mentioned, are:

– Sulphur compounds: causes deactivation of catalyst active centres
– Halogens: causes corrosion of catalysts
– Nitrogen compounds: causes amine formation (e.g. in methanol synthesis) and adds to smell to the product
– Tars: coat and cover catalysts by gum formation on the surface

The remainder of Workshop presentations gave an overview of the different gas cleaning methods and about the different analytical methods employed to characterize synthesis gas. An overview of the different analytical methods can be found at the homepage of the task:
http://media.godashboard.com//gti/IEA_WS_SynthesisGas_10-07l.pdf

One topic, where Austria is already a long time engaged, is the **health and safety** topic of biomass gasification systems. The third meeting in the Triennium was focusing on this topic and the headline was “On the Way to Safe and Eco-friendly Biomass Gasification”. This workshop was organised by the EC-project “Gasification Guide”, by GasNet, and by the Task. The main focus of this work is to simplify for the constructors and operators of biomass gasification system the health and safety issues. In this way also the permitting process should be simpler for gasification plants. More information can be found: http://www.gasification-guide.eu

A workshop on “**Operating experience of biomass gasifications systems**” is traditionally the last workshop of a Triennium. From the 9 presentations at this workshop, 3 were from Austrian developments (Güssing see 4.2.1, page 15; Oberwart see 4.2.2, page 16; Technical University Graz). Jürgen Karl (Institute for Thermal Engineering, Graz University of Technology) gave a presentation of “10 years Biomass Heatpipe Reformer” beginning with 1999 and the development till 2010. The technical challenges of heatpipe reformers to produce syngas are fuel feeding, fuel flexibility, hydrogen diffusion and gas quality. Most of the problems could be solved. Heatpipes could be integrated in different applications: CHP with gas engines (pressure improves specific power and efficiency) and micro turbines (simple hot gas cleaning), CHP with fuel cells (plant at TU Munich) and substitute natural gas by Syngas from biomass (thermal gasification and methanation), which seems to be a possible solution to use biomass after methanation in urban areas with high efficiency and without fine dust emissions (Details http://media.godashboard.com//gti/IEA_Task33_ws_karl_nov2009.pdf).

As general conclusion from the different presentations it can be said, that using the product gas without any gas cleaning works very well. The main difficulties in operating biomass gasification systems were on the one side on the fuel feeding system and on the other side on the gas treatment. The gas cleaning for CHP applications has been developed during the last years to a level, that already several plants are in operation, but is has to be mentioned, that there were also several problems. Especially the plant in Güssing was mentioned several times as an excellent example for a successful development. For more advanced applications like synthesis of chemicals and fuels the status is still on a research and development, but also some demonstration projects are coming up. Here also the biomass plant at Güssing is a positive example, as there much R&D, but also demonstration is done on different synthesis applications.

The presentations and the summary of the workshop can be found at the homepage: http://www.gastechnology.org/webroot/app/xn/xd.aspx?it=enweb&xd=iea/taskminutes.xml.

7. Know-how Transfer

The coordinator of the Austrian projects in IEA Bioenergy, JOANNEUM RESEARCH, collects information and studies from the individual tasks, passes these to interested parties and provides these also on request (Email: kurt.koenighofer@joanneum.at). Information and documents from the regular Executive Committee (ExCo) meetings (twice per year) are available for task participants and interested parties. Immediately after the ExCo meetings a summary about the contents concerning the Austrian Tasks is prepared and forwarded to Austrian Task participants. The regular national expert meetings „IEA Network Meeting“ and „Highlights of Bioenergy Research“ inform about news in IEA Bioenergy and the Austrian participation.

In close cooperation with M. Wörgetter (FJ-BLT Wieselburg) JOANNEUM RESEARCH reports regularly about the Austrian activities in IEA Bioenergy in the periodical "Nachwachsende Rohstoffe" special part IEA Bioenergy (see http://blt.josephinum.at/index.php?id=342). Alternating the current work of each task is presented. Supplementary Austrian relevant contents of IEA Bioenergy, e. g. results from ExCo-meetings, announcement of workshops and meetings, new publications, are provided.

J. Spitzer informed about the organization and strategic orientation of IEA Bioenergy („Strategic Plan 2010-2016“, http://www.ieabioenergy.com/DocSet.aspx?id=6338&ret=lib), the Austrian participation starting from 2010, technology developments and political discussions about biofuels and changes of land use within the network meeting on 24. November 2009. The program and the lectures are available to download (see http://energytech.at/(de)/results/id5793.html).

Together with JOANNEUM RESEARCH the BMVIT organizes the expert meetings „Highlights of Bioenergy Research“. Each meeting focuses on one topic, concerning studies and results from IEA Bioenergy Tasks and Austrian research projects as well as practical oriented projects are presented.

The first meeting „Highlights of Bioenergy Research I“ with focus on „biofuel production“ and „development of biomass potentials“ was organized on 28. April 2009 in Vienna. It was reported about the Austrian participation in IEA Bioenergy, furthermore about studies and results in Task 33 “Thermal Gasification of Biomass”, Task 39 “Commercialising Liquid Biofuels from Biomass” and Task 40 “Sustainable International Bioenergy Trade - Securing Supply and Demand“. The program and the presentations are available to download (http://energytech.at/(de)/results/id5573.html).

Within the meeting „Highlights of Bioenergy Research II“ on 12.11.2009 it was reported about newest developments in IEA Bioenergy in the field of „electricity and heat - advanced burning technologies“, furthermore about topics in Task 32 „Biomass Combustion and Co-firing“ and in Task 37 „Energy from Biogas“. The program, all presentations and the conference report are available to download (see http://energytech.at/(de)/results/id5751.html).

The website “NachhaltigWirtschaften.at” presents IEA Bioenergy and the Tasks with Austrian participation (http://www.nachhaltigwirtschaften.at/iea), and offers publications and presentations of the national meetings to download. Future meetings in the framework of IEA Bioenergy are announced.

Publications of IEA Bioenergy (e. g. „IEA Bioenergy Newsletter“, „Annual Report“ 2007 to 2009, „IEA Open Energy Technology Bulletin“, publications from workshops of the ExCo meetings, publications from IEA Series „Energy Technology Essentials“, „IEA Secretariat report“) and information about tasks (like announcement of meetings, publications, news on the task homepages) were distributed to national and foreign interested parties by email. Publications are available on the IEA Bioenergy website to download (http://www.ieabioenergy.com/Index.aspx).

Task 33 publications (e.g. Draft reports, presentations of workshop and Minutes of Meeting, chapter 6) are available on the Task 33 website (http://www.ieatask33.org).

8. Conclusions and Outlook

During the triennium 2007-2009 work in Task 33 focused on evaluating the state-of-the-art of biomass gasification RD&D and to understand the technical and non-technical hurdles to advance the state-of-the-art and commercialization of Biomass Gasification (BMG), forming strategic partnerships with participating member countries and industries to initiate new RD&D projects, advising government agencies on matters pertinent to national bioenergy initiatives, and undertaking appropriate joint efforts with other selected bioenergy tasks to investigate technologies and technical issues of mutual interest.

The Austrian National Team Leader (NTL) had to summarize the analytical methods for **characterization of synthesis gas** and to identify possible impurities. E.g. these impurities effect on the lifetime of catalysts. Normally catalysts have useful lives of 2 – 5 years. The challenge for development of synthesis gas conversion with any new catalyst is the prevention of deactivation.

One topic, where Austria is already a long time engaged, is the **health and safety** topic of biomass gasification systems. The main focus of this work is to simplify for the constructors and operators of biomass gasification system the health and safety issues. In this way also the permitting process should be simpler for gasification plants.

As general conclusion from **Operating experience of biomass gasifications systems** it can be said, that using the product gas without any gas cleaning works very well. The main difficulties in operating biomass gasification systems were on the one side on the fuel feeding system and on the other side on the gas treatment. The gas cleaning for CHP applications has been developed during the last years to a level, that already several plants are in operation, but is has to be mentioned, that there were also several problems.

Especially the plant in Güssing was mentioned several times as an excellent example for a successful development. For more advanced applications like synthesis of chemicals and fuels the status is still on a research and development, but also some demonstration projects are coming up. Here also the biomass plant at Güssing is a positive example, as there much R&D, but also demonstration is done on different synthesis applications (e.g. FT-Diesel, SNG).

Outlook for 2010-2012

The proposed approach and methodology should progressively improve upon the scope of work conducted in the previous Activities and Tasks. The proposed work will include elements from the last triennium and address the issues raised in the preceding sections on Barriers to Technology Commercialization and Additional Drivers for Advancing BMG:

At the Task Meetings information exchange is usually the very first technical discussion item on the Agenda. By virtue of their professional interests, NTLS regularly survey the progress made in the development and commercialization of BMG. The Task Meetings provide the forum to share and discuss the merits of these developments and to identify demonstrated technical progress as well as the lessons learned, while also addressing research needs and identifying new direction for R&D and deployment, e.g. green chemistry. This information is useful to revise and update the state-of-the-art of BMG and to identify the drivers and the prevailing barriers to advance the technology.

The information exchanged at the Task Meetings, will be useful for compiling Country Reports, summarizing for each country its biomass resources, national policies, drivers for biomass utilization, the national BMG RD&D and commercialization programs, projects, and plans. Draft reports prepared and posted on the Task website (http://www.ieatask33.org) will be periodically updated as new information becomes available.

Bibliography

IEA Bioenergy Publications http://www.ieabioenergy.com/Library.aspx

/1/ Annual Reports (Jahresberichte)

/1/ IEA Bioenergy Annual Report 2006
http://www.ieabioenergy.com/LibItem.aspx?id=5429

/1/ IEA Bioenergy Annual Report 2007
http://www.ieabioenergy.com/LibItem.aspx?id=5761

/1/ IEA Bioenergy Annual Report 2008
http://www.ieabioenergy.com/LibItem.aspx?id=6124

/2/ Newsletter

/2/ Bioenergy News Volume 19 Nr. 1, July 2007
http://www.ieabioenergy.com/LibItem.aspx?id=5572

/2/ Bioenergy News Volume 19 Nr. 2, December 2007
http://www.ieabioenergy.com/LibItem.aspx?id=5729

/2/ Bioenergy News Volume 20 Nr. 1, June 2008
http://www.ieabioenergy.com/LibItem.aspx?id=5572

/2/ Bioenergy News Volume 20 Nr. 2, December 2008
http://www.ieabioenergy.com/LibItem.aspx?id=6075

/2/ Bioenergy News Volume 21 Nr. 1, July 2009
http://www.ieabioenergy.com/LibItem.aspx?id=6327

/2/ Bioenergy News Volume 21 Nr. 2, December 2009
http://www.ieabioenergy.com/LibItem.aspx?id=6487

/3/ Reports, presentations (Berichte, Präsentationen) etc.

/3/ MAIN REPORT "Bioenergy - a sustainable and reliable energy source. A review of status and prospects", December 2009
http://www.ieabioenergy.com/LibItem.aspx?id=6479

/3/ Workshop: Algae - the Future for Bioenergy?, October 2009
http://www.ieabioenergy.com/DocSet.aspx?id=6436&ret=lib

/3/ Bioenergy – a Sustainable and Reliable Energy Source (Executive Summary), August 2009
http://www.ieabioenergy.com/LibItem.aspx?id=6362

/3/ Workshop: The Impact of Indirect Land Use Change (ILUC), May 2009
http://www.ieabioenergy.com/DocSet.aspx?id=6214&ret=lib

/3/ Workshop: Planning for the New Triennium 2010-2012, May 2009
http://www.ieabioenergy.com/DocSet.aspx?id=6213&ret=lib

/3/ Good Practice Guidelines: Bioenergy Project Development and Biomass Supply, March 2009
http://www.ieabioenergy.com/LibItem.aspx?id=6119

/3/ Workshop: Energy from Waste: summary and conclusions, March 2009
http://www.ieabioenergy.com/LibItem.aspx?id=6115

/3/ Synergies and Competition in Bioenergy Systems, February 2009
http://www.ieabioenergy.com/LibItem.aspx?id=6103

/3/ Workshop: Biofuels for Transport: Part of a Sustainable Future? - summary and conclusions, December 2008,
http://www.ieabioenergy.com/LibItem.aspx?id=6068

/3/ Workshop: Innovation in Bioenergy Business Development: summary and Conclusions, November 2008
http://www.ieabioenergy.com/LibItem.aspx?id=6054

/3/ Gaps in the Research of 2nd Generation Transportation Biofuels, July 2008
http://www.ieabioenergy.com/LibItem.aspx?id=5955

/3/ Status and outlook for biofuels, other alternative fuels and new vehicles, June 2008
http://www.ieabioenergy.com/LibItem.aspx?id=5919

/3/ Workshop: The Availability of Biomass Resources for Energy: Summary and Conclusions; March 2008
http://www.ieabioenergy.com/LibItem.aspx?id=5796

/3/ Black Liquor Gasification – Summary and Conclusions, September 2007
http://www.ieabioenergy.com/MediaItem.aspx?id=5609

/3/ Potential Contribution of Bioenergy to the World's Future Energy Demand, September 2007
http://www.ieabioenergy.com/LibItem.aspx?id=5584

/3/ Workshop: The Biorefinery Concept, May 2007
http://www.ieabioenergy.com/DocSet.aspx?id=5476

/3/ IEA Bioenergy Strategic Plans; July 2009
http://www.ieabioenergy.com/DocSet.aspx?id=6338&ret=lib

Publications Austria (Veröffentlichungen Österreich)

Zeitschrift Nachwachsende Rohstoffe http://blt.josephinum.at/index.php?id=342

Nachwachsende Rohstoffe – Mitteilungen der Fachbereichsarbeitsgruppen, Nr. 43 – März 2007, http://www.blt.bmlfuw.gv.at/vero/mnawa/nr43.pdf

Nachwachsende Rohstoffe – Mitteilungen der Fachbereichsarbeitsgruppen, Nr. 44 – Juni 2007, http://www.blt.bmlfuw.gv.at/vero/mnawa/nr44.pdf

Nachwachsende Rohstoffe – Mitteilungen der Fachbereichsarbeitsgruppen, Nr. 45 – September 2007, http://www.blt.bmlfuw.gv.at/vero/mnawa/nr45.pdf

Nachwachsende Rohstoffe – Mitteilungen der Fachbereichsarbeitsgruppen, Nr. 46 – Dezember 2007, http://www.blt.bmlfuw.gv.at/vero/mnawa/nr46.pdf

Nachwachsende Rohstoffe – Mitteilungen der Fachbereichsarbeitsgruppen, Nr. 47 – März 2008, http://www.blt.bmlfuw.gv.at/vero/mnawa/nr47.pdf

Nachwachsende Rohstoffe – Mitteilungen der Fachbereichsarbeitsgruppen, Nr. 48 – Juni 2008, http://www.blt.bmlfuw.gv.at/vero/mnawa/nr48.pdf

Nachwachsende Rohstoffe – Mitteilungen der Fachbereichsarbeitsgruppen, Nr. 49 – September 2008, http://www.blt.bmlfuw.gv.at/vero/mnawa/nr49.pdf

Nachwachsende Rohstoffe – Mitteilungen der Fachbereichsarbeitsgruppen, Nr. 50 – Dezember 2008, http://www.blt.bmlfuw.gv.at/vero/mnawa/nr50.pdf

Nachwachsende Rohstoffe – Mitteilungen der Fachbereichsarbeitsgruppen, Nr. 51 – März 2009, http://www.blt.bmlfuw.gv.at/vero/mnawa/nr51.pdf

Nachwachsende Rohstoffe – Mitteilungen der Fachbereichsarbeitsgruppen, Nr. 52 – Juni 2009, http://www.blt.bmlfuw.gv.at/vero/mnawa/nr52.pdf

Nachwachsende Rohstoffe – Mitteilungen der Fachbereichsarbeitsgruppen, Nr. 53 – September 2009, http://www.blt.bmlfuw.gv.at/vero/mnawa/nr53.pdf

Nachwachsende Rohstoffe – Mitteilungen der Fachbereichsarbeitsgruppen, Nr. 54 – Dezember 2009, http://www.blt.bmlfuw.gv.at/vero/mnawa/nr54.pdf