DRAFT MINUTES
IEA Bioenergy Agreement
Task 33: Thermal Gasification of Biomass
Fall 2005, Task Meeting, September 26-28, 2005
Innsbruck, Austria
Prepared by
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December 5, 2005

The fourth Task Meeting for the 2004-2006 triennium was held from September 26-28, 2005 in Innsbruck, Austria. The fourth Task Workshop on Health, Safety, and Environmental Impact of Small Scale Biomass Gasification Systems (HSE) was held in partnership with European GasNet on Wednesday, September 28, 2005.

The participants in the Task Meeting include: Nick Barker, UK, Pekka Simell, VTT, Emanuele Scoditti, IT, Chris Williamson, NZ, Ruedi Buhler, CH, Reinhard Rauch, AT, Martin Wittrup Hansen, DK, Henrik Christiansen, DK, Nader Padban, SE, Eckhard Dinjus, DE, Edmund Heinrich, DE, Bram van der Drift, NL and Suresh Babu, USA. The participants in the HSE Workshop are listed in Attachment 1.

Apologies were received from: Richard Bain, USA and Maria Fernandez-Guittierez, EC for their inability to attend the Task Meeting.

The Agenda for the Task Meeting is shown in Attachment 2.

Day 1 and 2: Monday, September 26 and Tuesday, September 27, 2005: Task Meeting

The proposed Agenda was approved and the Minutes from the Spring 2005, Task Meeting held on May 17, 2005 in Stockholm, Sweden were approved with minor corrections.

Country Updates

The following is a summary of the updates, presented by the participants on the status of biomass gasification (BMG) research, technology development, demonstration, and commercialization in their respective countries:

Germany: At present, Germany's primary interest is in developing BMG for CHP and for producing organic base chemicals and fuels. The CHP plants are usually small scale

units, many of these are in early stages of commercialization. A good overview of the CHP systems was prepared by Fördergesellschaft Erneuerbare Energien e.V., Berlin (FEE, e-mail: FEE-eV@t-online.de (fee-ev))

For economic reasons, the synthetic fuels and organic base chemicals processes have to be implemented at a large scale. At present these processes are being evaluated in pilot plants.

Lists of Germany's key waste and biomass gasification projects are given below:

Table: 1 List of Key Waste gasification Projects

Company/ Process	**Type**	**Capacity**	**Feed stock**	**Status**
Rüdersdorf cement plant	Circulating fluidized bed	100 MWth	Wood waste	com. Op**.
SVZ Schwarze Pumpe	5 Fixed bed Fixed bed (BGL) + Entrained flow (GSP)	≈ 3 MWth	Brown coal + urban waste mix	com. op.
Thermoselect EnBW	fixed bed	≈ 100 MWth	Urban waste	com. op. shut down
Noell Conversion pilot plant	Entrained flow	3-5 MWth	Hazardous waste, flexible	pilot

**- com. op.: commercial operation

Table 2: List of BMG Projects

Company/ Process	**Type**	**Capacity**	**Feed materials**	**Pressure**	**Status**
SVZ Schwarze Pumpe commerical methanol	Fixed bed + Pressurized GSP entrained flow	130 MW_{th} entrained flow	Waste mix brown coal	25 bar	see Table 1 com. op.
Choren Carbo-V	atmospheric CGT entrained flow	1 MW_{th} (45 MW_{th}) (pressurized)	Wood	4 bar (30 bar)	pilot
Future Energy + FZK BtL-process	Pressurized GSP entrained flow	5 MW_{th} (2 MW_{th})	Straw, wood	26 bar (80 bar)	pilot in progress
CUTEC	Circulating fluidized bed	0.4 MW_{th}	Wood, straw	atm.	pilot
UMSICHT	Circulating fluidized bed	0.5 MW_{th}	Wood, straw	atm.	pilot
D.M.2 "Blue Tower"	Fixed bed + heat carrier	1 MW_{th}	Wood, straw, waste	atm.	pilot

The GSP-type (Gaskombinat Schwarze Pumpe) entrained flow gasifier at Schwarze Pumpe, near Freiberg has been in operation since 1988. The pressurized water cooling screen (maintained at ~ 250 °C) which protects the high-temperature gasifier with a condensed layer of slag has been checked by visual inspection and found to be in satisfactory condition.

The CHOREN Carbo-V process involves first subjecting biomass to low temperature partial oxidation at 500°C followed by high temperature gasification of gas and tars at about 1400°C, and endothermic entrained flow gasification of the remaining pulverized char and other components at about 800°C. The resulting synthesis gas, free of tar, has been converted to fuels by Fischer-Tropsch synthesis and to methanol. A 15.000 TPY fuels and chemicals demonstration plant is being planned for installation in Freiberg with start-up in 2007. Shell may deploy the first commercial FT-production plant.

Since 1996, the Fraunhofer Institute UMSICHT in Oberhausen has been conducting tests for over 1600 hours, in a 0.5 MWth CFBG.pilot unit, at feed rates of 70 to 120 kg/h of wood. Based on these tests, plans are underway to build a 1-5 MWth CHP and a 5 MWth demonstration plant.

Future Energy's 3-5 MWth pressurized entrained flow gasifier produces a tar and CH4-free raw gas, with C-conversion > 99 %, at very short residence times (seconds) and at high throughput rates. This gasifier with fast start and shut-off capabilities is suitable for any type of pulverized or pumpable fluid feed. The cooling screen described above is employed in the GSP-type gasifier and it has been proven to successfully handle ash- and salt rich fuels for extended periods of operation.

The Forschungszentrum Karlsruhe, Institut für Technische Chemie, CPV (FZK), is developing the "Karlsruher BtL Process" concept, which is supported by the EU-project RENEW and Baden-Württemberg state ministry of agriculture. The concept involves pyrolyzing biomass, such as straw, with an energy density of 2 GJ/m3, in distributed pyrolyzers (located with in a radius of 25 km) and transporting the pyrolysis liquids (with an energy density of around 16 GJ/m3) to a central gasification and synthesis gas conversion plant, similar to a typical oil refinery with a capacity of about 1 MTOE/yr.

So far, FZK conducted four gasification test campaigns using the GSP-gasifier at Future Energy in Freiberg. These included gasification of bioslurries from pyrolysis oils mixed with char, derived from wood and straw. Tests were conducted at1200-1600 °C, 26 bar, with slow pyrolysis products of wood and straw and the fast pyrolysis biooil from Dynamotive bioslurries (LHV 10-24 MJ/kg, 20–40 % wt solids content) at slurry throughput rates of 0.35 – 0.6 TPH. The tar-free product gas is a low-methane, typically < 0.2 % vol., content synthesis gas.

A Hydrothermal biomass Gasification process, operating at about 600°C and 350 bar is being tested in the 100 kg/h pilot test unit "Verena". The tar-free product gas is mostly H2 and CH4; the CO2 contained in these gases can be easily separated.

Austria: In 2003, Austria derived 21% its energy from renewable resources while biomass contributed roughly 12% (or 168 PJ or 0.16 Quads) of the primary energy demand. Of the latter, 60% is used for heating applications, 21% for process heat, 11% for CHP, and 8% for district heating. Thus, most biomass is used for heating applications.

By the end of September, 2005, the 8 MWth, TUV-FICFB Güssing demonstration plant has logged-in nearly 19,000 hours of, gasifier operation which includes more than 15,000 hours of integrated operation with the ~ 2 MWe, GE-Jenbacher engine. A variety of raw gas slip-stream conversion studies are being conducted at this demonstration plant to evaluate the production of SNG and biodiesel type fuels. The other BMG projects at TUV include RENEW (F-T biofuels coordinated by Volkswagen AG), AER – Gas II (CO_2 removal with CaO in the gasifier), Big Power, BioSNG (evaluation of co-shift and SNG catalyst coordinated by PSI, CH), and the development of a pressurized gasification process for SOFC applications. The Institute of Thermal Engineering at the Graz University of Technology is investigating the performance and optimization of a fixed-bed gasifier and gas engine system, similar to the Viking BMG power generation system. Tests are continuing at the Wr. Neustadt gasifier to evaluate tar removal by scrubbing raw gases with biodiesel to remove tars.

Denmark: The 1996 "Energy 21" policy is the prevailing foundation for Danish Energy programs. The budget for renewables RD&D in 2005 increased by 50% compared to the previous year. The incentive for "green power" is in the guaranteed electricity price of about 60 ore or about 8 Eurocents/KWh.

The new BMG initiatives include the on-going construction of the Carbona CHP project at Skive. The project is funded with Public Service Obligation of DK 130MM, (besides support from USDOE). In addition, a low-temperature chicken litter gasification plant is under development. The Viking Process is being scaled-up to a 500 KWth system. Freight trucks are now transporting straw pellets, up to 40 tons/truck, from rural areas to city centers. Among the renewable technologies, the Danish windmills are now generating power at 2.2 Eurocents/KWh.

European Commission: The projects selected from the proposals submitted for the first medium to long-term (MLT) solicitation are listed below:

1) Clean hydrogen-rich synthesis gas – CHRISGAS: To develop a large scale BMG process to produce clean hydrogen-rich gas that can be used for the production of transportation fuels. The key research facility is the pressurized BMG plant in Värnamo, Sweden; Coordinator: Växjö University, Sweden and EU support = 9.5 million €.

2) Renewable fuels for advanced power trains - RENEW: To compare and (partially) demonstrate a range of fuel production chains for motor vehicles; Coordinator: Volkswagen AG, Group Research, Germany and EU support = 10 million €.

3) Overcoming barriers to bioenergy – NoE BIOENERGY: Covering all processes, components and methods necessary for establishing successful bioenergy chains to produce heat, electricity and fuels; Coordinator: Volkswagen AG, Group Research, Germany and EU support = 10 million €.

4) Ash and aerosol related problems in biomass combustion and co-firing – BIOASH: Coordinator: TU Graz, Austria and EU support = 2.34 million €.

5) Synergy effects of co-processing biomass with coal and non-toxic wastes for heat and power generation – COPOWER; Coordinator: Ineti, Portugal and EU support = 2.06 million €.

6) New burner technologies for low grade biofuels to supply clean energy for biorefineries – BIOPRO; Coordinator: University of Stuttgart, Germany and EU support = 2.2 million €.

7) Biomass fuel cell utility systems – BIOCELLUS: Coordinator: TU München, Germany and EU support = 2.5 million €.

8) SOFC fuelled with biomass gasification gas – GREENFUELCELLS; Coordinator: Cirad, France and EU support = 3 million €.

9) Renewable energy from crops and agrowastes – CROPGEN; Coordinator: University of Southampton, UK and EU support = 2.1 million €.

The selection process is now in progress for the second call for "Sustainable Energy Systems Work Group." It is anticipated that 40 million € may be awarded as contracts for successful proposals/projects.

Italy: The current biomass research programs are driven by the National Program on Renewable Energies from Biomass developed in October 1998. The decree to issue green certificates was announced in November 1999. In addition to conventional fuels, Italy produces about 500,000 TPY of extracted residual olive cake. The following is a summary of key BMG R&D projects:

1) Clean Energy (Hydrogen) from Biomass: Coordinated by University of L'Aquila, with participation from ENEA and TUV, Austria.

2) Updraft BMG with Power Generation: Coordinated by Legnano (VA), with participation by Guascor.

3) 4.5 MWe, downdraft gasification with olive cake using Prime Energy System: Coordinated by Rossano (CS) with participation from Guascor.

4) 3 MWth, updraft BMG (including coal, wood and RDF): Coordinated by Ansaldo Ricerche, Genova; tests in progress.

5) 3 MWth, updraft BMG; Coordinated by Marcegaglia Group in Taranto; tests in progress.

6) 15kW_e downdraft fixed bed, 80 kW_e downdraft fixed bed, and a multi-fuel 160 kW_e Fluid Bed BMG systems; Coordinated by ENEA, Trisaia. The first two are on stand-by and the third plant is in operation in China.

New Zealand: About 237 PJ of renewable energy was produced in 2004; New Zealand's total annual energy consumption is equal to 765 PJ in 2004. Of the renewable energy used, woody biomass make up 35 PJ in 2004, increasing to 50 PJ in 2010. Fluidyne (www.fluidynenz.250n.com) scaled up the moving bed technology to a 2 MWe plant that is undergoing tests in Canada. AB Powerhearth Ltd. (www.3alternativepower.com) has

developed a 3 MWe downdraft BMG system for commercialization in U.S.A. The 2 MWth co-firing, updraft Page Macrae BMG plant is now in operation.

The University of Canterbury is now building a laboratory-scale TUV-FICFB gasifier for testing and evaluation for power generation and other applications.

Switzerland: The operation of Xylowatt BMG plant was suspended because of the frequent need for gas cleaning required to keep the gas engine operating. More problems were encountered with particulates compared to tar. As a consequence, Xylowatt has stopped all activities in BMG. The Pyroforce BMG has been operating successfully. Future plans include building two 350 KWe Pyroforce BMG plants in Güssing and there are several new projects under consideration in Switzerland and Germany. So far five Pyroforce gasifiers have been commissioned.

Sweden: Biomass programs were driven by the Energy Policy Act of 1997, with the objective to ensure, in both the short and long terms, a reliable supply of electricity and other forms of alternative energy on competitive terms. The strategy for restructuring the country's energy system includes implementing short-term programs (replacing the loss in production resulting from the closure of Barsebäck nuclear plant), providing investment subsidies (approx. 25% for biomass CHP, 15% for wind and micro-hydro), initiating long-term RD&D programs, implementing politically justified measures to counter climate change, and imposing landfill tax to ultimately comply with the EC directive prohibiting the land-filling of organic materials.

The objective of the New Energy Policy Act of 2002 is to create the right conditions for efficient use and cost-efficient supply of energy in Sweden, with minimum adverse effects on health, the environment and climate, while at the same time supporting the move towards an ecologically sustainable society. The strategy includes, increasing the thrust of the guide measures in the shorter term and increase taxes on energy, emissions etc., reduce direct labor requirement, incentives for RE electricity, and the efficient use of energy with innovative co-generation applications.

The trading of RE certificates has been in progress since 2003. The RE quota of 7% in 2003 will increase to 17 % in 2010. The target is to build 10 TWh of additional RE capacity by 2010.

Current R&D Programs

Universities:
1. KTH is active within CHRISGAS project
2. Luleå, Umeå and Chalmers are working on black liquor gasification
3. Växjö University and Mitthögskolan, Härnösand are in early stages of BMG R&D
4. Lund has been inactive since 2000

Industries:
1. TPS, SEP, and Ducente are active with in the CHRISGAS project

2. Chemrec is active with the in new BLG program and in the RENEW project
3. Vattenfall and Sydkraft are not actively engaged in any R&D programs
4. The Götaverken CFB Gasifiers, commissioned in 1987, at Värö pulp mill are fuelled by bark and wood wastes. The fuel capacity is 30 MWth. The fuel gas is used in a lime kiln. In 2003, enriched air was used to de-bottleneck the lime kiln capacity. The Foster-Wheeler units at Norrsundet and Karlsborg are still in operation.
5. The specifications of the Värnamo, Bioflow CHP gasifier supplied by Ahlstrom/FWE and Sydkraft are:

Fuel- 18 MW
Power - 6 MW
Heat- 9 MW
18 bar pressure for integrated operation with Typhoon GT

The Värnamo plant was mothballed in 2000, after more than 8,000 hours of gasifier and 3,600 hours of integrated operation with the gas turbine. The plant emissions were low in CO and THC. The facility is reactivated as the Växjö Värnamo Biomass Gasification Center AB, as one of the prominent European center piece for R&D of the CHRISGAS project. One of the primary missions of this project is to start production, within 3-4 years , clean hydrogen-rich gas from biomass fuels at a rate of 3,500 Nm3/hr .

The R&TD Deliverables for the CHRISGAS project are:

- Test new drying and feeder systems,
- Conduct tests and obtain operational data at 3-4 TPH, and
- Evaluation of catalysts, filters, gas cleaning systems etc. used at Värnamo.

The ultimate goal of the CHRISGAS Project is to produce bio-fuels at a price competitive with current fuel prices. Other deliverables include development of a web based educational package involving academic research organizations.

The CHRISGAS Project partners are given below:
Sweden:Växjö University (co-ordinator), Växjö Värnamo Biomass Gasification Centre (VVBGC), AGA-Linde, Catator, KS Ducente, Royal Institute of Technology (KTH), S.E.P. Scandinavian Energy Project, TPS Termiska Processer, (Valutec), and Växjö Energi
Denmark: TK Energi
Finland: Valutec
Germany: FZ Jülich, Linde, and Pall Schumacher
Italy: University of Bologna
Netherlands: Technical University Delft, and
Spain: CIEMAT.

The project is financed by € 9.5 MM grant, € 1.5 MM STEM grant and € 7 MM grant from others. The project was launched in October 2005.

The on-going Värnamo Plant modifications will include installing a steam/oxygen distributor, a new hot gas filter system, and the installation of a catalytic high temperature reformer.

USA: The vision of the U.S.A's biomass program is focused on producing substitutes for imported oil, energy security, and sustainable energy supply. Partnership with industry is an important component. R&D focus is on integration of thermal gasification with biochemical conversion processes, to maximize the overall thermal efficiency of biomass conversion. The "Integrated Biorefinery" concept advocates fractionation of biomass in order to separate and direct the non-fermentable components as the feedstock for gasification. The fuel gas, power and waste heat from gasification is closely integrated to supply the energy requirements for biochemical conversion of the fermentable fraction of the biomass. Close integration should lead to conserving energy and improve the overall thermal efficiency. The integrated process could produce a variety of fuels and chemicals that could substitute for petroleum derived products.

Two recent independent studies concluded:

1) Harvesting and processing 1.3 billion tons of biomass/year could match the current supply of oil produced in U.S.A. 1.3 billion tons of biomass/year is also equivalent to 60% of the current demand for petroleum in the U.S. At present, U.S. produces about 2 billion barrels of oil/year and imports an additional 4.3 billion barrels of oil/year.
2) U.S. can meet the current fuel demand for light and heavy duty applications, using biomass (derived fuels) produced from about 16% of U.S. agricultural land.

   Based on these studies, three strategies are under consideration:

   i) Seed new technology components to develop integrated biorefineries in existing fermentation facilities by 2007
   ii) Scale-up the first generation integrated biorefineries by 2012
   iii) Develop advanced large-scale integrated biorefineries to displace petroleum by 2020+

Gas Clean-up Research: The NREL R&D investigations include high temperature and high-pressure synthesis gas conversion to produce preferably fuels and chemicals, with the option to produce H_2 and export electricity. The tolerable limits of raw gas impurities for synthesizing fuels and chemicals re listed below in Table 3:

Table 3. Tolerance levels of contaminants for Synthesis of Fuels

	Level	**Source**
Particulate	0, > 2µm	Tijmensen, *et al.* 2002
Tar	0 ppm	Jackson, *et al.* 1995
Sulfur	0.2 ppm	Dry, 1981
	1 ppmv	Boerrigter, *et al.* 2002
	60 ppb	Turk, *et al.* 2001
Halides	10 ppb	Boerrigter, *et al.* 2002

Nitrogen	10 ppmv NH_3	Turk, *et al.* 2001
	0 ppmv NOx	
	10 ppb HCN	

A summary of the tolerance limit of raw gas contaminants for selected advanced BMG applications is given in the following table:

Table 4. Tolerance limits of Raw Gas Contaminants

Contaminant		**Turbine**	**SOFC**	**Chemicals**
Sulfur	ppmv	20	1 – 0.05	0.2 – 0.01
Halides	ppmv	1	1 – 0.01	0.1 – 0.01
Ammonia	ppmv		5000	10 – 0.02
Sodium + Potassium	ppmw	0.08		0.01
Particles (total)	ppmw	3.0	?	0
Particles (5-10 µm)	ppmw	0.15		
Particles > 10 µm	ppmw	0.03 - 0		
C_2-C_6	ppmv		2000	? (low)

Quoting Parkinson, "Chemical Engineering Progress, May 2005" on reforming light hydrocarbons and synthesis gas conversion, NREL reports that the "gasification island" constitutes 60% while "Synthesis Island" makes up the remaining 40% of the overall capital cost. Further, it is observed that by minimizing or eliminating methane content in raw gases, up to 50% of the capital cost for the synthesis gas island can be reduced.

The raw-gas tar reforming options include both metallic (ex: Ni, Rh, Ru, and Pt) and non/metallic (ex: dolomites, olivine and lime stones) catalysts at temperatures up to 900^0C. Catalyst poisons in raw BMG product gas include S, Cl, and alkaline compounds. A list of the state-of-the-art, on-line analytical instruments used for characterizing gas streams is given below:

- Non-dispersive infrared (NDIR) analyzer for CH_4 (range: 0-50 vol%)
- NDIR analyzers for CO_2 and CO (range: 0-50 vol%)
- Paramagnetic oxygen analyzer (range: 0-25 vol%)
- H_2 thermal conductivity analyzer (range: 0-50 vol% and analog inputs for %CO, $\%CH_4$ and $\%CO_2$ to correct the H_2 value)
- Quad micro gas chromatograph
  4 channel, on-line GC with 2-3 min cycle time
  H_2, O_2, N_2, CH_4, CO, CO_2, C_2H_6, C_2H_4, C_2H_2, C_3H_8, and C_4 paraffins and olefins
- Transportable molecular beam mass spectrometer (TMBMS)
  Continuous, real-time monitoring of all gas phase products with particular emphasis on condensable tars and heteroatom compounds

The Netherlands: The Netherlands is introducing tax incentives to promote addition of 2% liquid biofuels. These may amount to €70 MM in 2006. From 2007 onwards there will be mandatory addition of liquid biofuels, (probably) without tax incentive. An

additional €12 MM/yr will be provided from 2006-2010 for R&DD for second generation biofuels.

Biomass R&D is divided into 3 parts: 1) gasification, gas cleaning and gas conditioning, 2) electricity and heat, and 3) biorefining. ECN is recognized as dominant in the first part, ECN and KEMA will lead the second part. SenterNovem is trying to set up ERANET bioenergy programme involving NL, AT, FI, DE, SE, and UK.

HOST, the leading small-scale gasification system supplier, has built a 700 kg/hr, sunflower-husk gasifier in Romania. HOST is also building a chicken litter gasifier in Tzum NL, which should be commissioned shortly. Plans are under way to build a 2100 kg/hr plant in Moldavia.

The Essent BMG plant has recently been handed over for commercial operation.

The BMG R&D projects at ECN include: Torrefaction, MILENA, a 5 kg/h allothermal gasifier which has been tested for over 100 h, testing and evaluation of TREC granular bed filter, development of lab-scale integrated BMG system for SNG production, and the OLGA gas clean-up process which has recently completed 500 hrs of operation.

The following is a list of key university research projects:

1. Eindhoven: plasma/corona, in-bed tar reduction, partial oxidation, cooler fouling.
2. Twente: self gasification, steam/iron process with bio-oil, super critical water gasification (with BTG)
3. Delft: CFB-gasification, high-temperature filter.
4. BTG is now focused on investigating supercritical water gasification and gasification of ash-free pyrolysis products.

FINLAND: Most of the original Bioneer plants are still in operation. The present focus is on biomass & waste gasification, particularly small-scale gasifiers for heat and CHP applications.

The 7 MWth Novel updraft gasifier at the Kokemäki CHP demonstration (producing 1.8 MWe), has been commissioned. The Kokemäki CHP plant employs low-temperature waste heat from the plant to dry wood fuels with 10 – 50 % moisture. Fuel capacity is 7200 kWth (6200 kWth without boiler). The design power output is 1800 kWe and the district heat output is 4300 kWth (3100 kWth without boiler). The low-level heat output to the fuel dryer is 430 kWth. The overall investment cost is 4.5 to 5 MM€. The construction work was completed in April 2005 and plant commissioning is now in progress. While initial start-up employs a single JMS 316 engine (600 kW), two more Jenbacher engines should be operational by the end of 2006. The estimated electrical efficiency of the waste to power is 30 to 35 % which can be raised at the CHP plant to 35 to 40 % by recovering heat from condensing flue gases.

The Entimos downdraft gasification plant has been shut down due to unsuccessful operation. Puhdas Energia Oy is testing and commercializing small downdraft gasifiers.

After 20 years of reliable operation the 35 MWth lime-kiln Ahlstrom/FWE CFB gasifier in Pietarsaari, built for boilers and kilns, has been shut down. The plant was shutdown because of new process integration requirements at the paper mill. The 60 MWth Ahlstrom/FWE CFB gasifier in Lahti has been in successful operation since 1988. Sofar, the Lahti Plant has logged in 35,000 operating hours, with current gasifier availability at > 95 %. The raw gas is cooled to 500^{o} C, Ca(OH)2 is injected for removing chlorides @ 350-500C, before the carry-over dust is removed in bag filters. By co-firing with BMG fuel gas, the boiler emissions have decreased. The estimated payback time for similar plants is about 8 years. A new, 160 MWth waste-to-energy plant is in the design phase for construction to replace the coal fired boilers in Lahti. The design includes two FWE CFB gasifiers, gas filtration, and a new boiler with WID flue gas cleaning system. The EC Trenn, IP project is under negotiation. The 40 MWth Corenso plastic waste FEW BFB gasifier has been operating successfully since 2001.

Carbona is building a 30 MWth BFB CHP gasification plant with gas engines in Skive, Denmark.

The main biomass and waste gasification RD&D activities at VTT include:

i) PDU gasification tests with auto shredder residues
ii) CFB gasification of plastics and fuel gas utilization in calcining kilns
iii) Evaluation of gasification of copper and arsenic-treated (CCA) wood in the Novel technology
iv) Catalyst development and design for Novel demonstration plant (evaluating Zirconia as a substitute for Ni for tar cracking)
v) Development of advanced synthesis gas production (Ultra Clean Gas or UCG project)
vi) Integrated process concepts (pulp and paper industry)
vii) Construction of a 10 bar, 500 kWth pressurized PDU at VTT for testing and evaluation of UCG processing methods. This project is financed by Tekes, VTT, Foster Wheeler, Fortum Oil, Andritz, Vapo with a budget of 4 MM€. When the construction is completed in 2006, a variety of synthesis gas conversion tests will be evaluated for producing liquid biofuels, process optimization, and integration with pulp and paper and refinery industries.
viii) Improvement of the economics of fluidized bed BMG processes by advanced ash management involving integrated oxidiser tests with wood derived and SRF derived filter dust at VTT.
viii)
ix) Support research for the Lahti IP project

The EC sponsored BiGPower project (Oct. 2005 to Sept 2008) will gasify waste-derived fuels and agro-biofuels, and conduct slip stream tests with second generation catalytic gas clean-up, water scrubbing, and to evaluate recycling of contaminants.

The advantages of waste gasification over incineration include:

- Lower investment costs compared to conventional incineration
  - 30-50 % when co-firing in existing power plants
  - 80-100 % with completely new gasifier-power plant
- Electrical efficiency up to 35-40 % instead of 25-30 % with incineration
- Low emissions
- Removal of Cl from fuel gases before the boiler eliminates boiler corrosion and dioxin formation
- Lowest cost for CO2 reduction when coal is replaced by clean waste derived fuel gas in existing power plants
- Good potential for material recovery and for realizing different recycling concepts

Hence, waste is too valuable to be incinerated or land-filled. The features of selected BMG processes are given in Table 5.

Table 5. Features of Finalnd's BMG Processes

Gasification method	Potential size, MW_{fuel}	Application	Required gas cleaning
Circulating Fluidised-Bed = CFB	20 - 150	boilers, kilns	cyclone: clean biomass filtration: waste-derived fuels, agrobiofules
Bubbling Fluidised-bed = BFB	10 - 50	boilers, kilns	same as CFB
BFB	10 - 50	engines	catalytic reforming + filtration + wet scrubbing
Novel Fixed-bed	1 - 10 ... 20	boilers, kilns	no cleaning: clean biofuels filtration: agrobiofuels, wastes
Novel Fixed-bed	1 - 10	engines	catalytic reforming + filtration + wet scrubbing
Pressurised BFB or CFB	50 - 300	gas turbines	filtration at 400-550 ^{o}C
O_2-blown or steam gasification	100 - 500	chemicals, H2, fuel cells	catalytic reforming + filtration + wet scrubbing + gas conditioning

VTT provided the following illustration of techno-economic analysis of a biosyngas Conversion:

Plant Capacity: 300 MWth of feedstock (LHV basis)
Annual operating time: 8000 hrs
Interest on capital: 10 % for 20 years
O&M costs: 4 % of investment

Base values for purchased/sold energy (other values applied in sensitivity case studies):

Feedstock: € 10 /MWh (LHV)
Electricity: € 30/MWhe
HP steam: € 16/MWh of transferred heat
MP and LP Steam: € 13/MWh of transferred heat

Fuel gas: € 14/MWh (LHV)

The estimated investment costs are:

Fischer-Tropsch primary liquids; once-through synthesis: € 210 MM
Fischer-Tropsch primary liquids; with reforming loop: € 230 MM
Methanol: € 220 MM
Synthetic Natural Gas: € 200 MM
Hydrogen, either via traditional method or via PSA separation: € 195 MM

Note: Steam refers to HP and LP steam produced in synthesis gas cooling and MP/LP steam produced in synthesis/shift. Overall efficiency of FT is exceptionally high (heat of condensation of product liquids and heat of condensation of part of product H2O recovered as LP steam). In comparison, the overall efficiency of methanol synthesis is low. Benefits of integration will show how the process steps and processes are sized and configured.

VTT's 25 year RD&D program vision includes:

1) Production of synthesis gas from biomass to produce liquid biofuels, hydrogen, synthetic methane and chemicals.
2) Production of liquid biofuels or H2 in medium-to-large scale plants. The 200 MWth HTW plant in Oulu will be conducted as an integral part of this mission.
3) Co-production of biofuel, H2, and energy in pulp and paper mills or at oil refineries employing fluid-bed gasifiers of 200-400 MWth capacity.

United Kingdom

The recent developments related to BMG include increasing support for CHP applications and energy recovery from wastes. Biomass Engineering continues progress with manufacturing six small (250kWe) commercial CHP units while three units are in operation. Compact Power has received a contract to build one 2MWe waste to energy unit. The renewed interest in renewable energy from industry is primarily due to high oil prices. There are few changes in the on-going R & D and demonstration activities.

To reiterate, UK's Target is to produce 10% of electricity from renewables by 2010, 15% by 2015, with the aspiration to raise the limit to 20% by 2020 and cut carbon dioxide emissions by 60% by 2050. Part of the CO2 reduction could be contributed by implementing Biofuels Directive to introduce 5% bio-transport fuel by 2010.

The present market drivers include the Renewables Obligation – electricity price of approx. €10.8 cent/kWh, rising oil and gas prices, landfill directive increasing wood disposal costs. The Royal Commission on Environmental Pollution Report on Biomass recommended further support for heat and CHP. A new initiative, The Biomass Task Force, has reinforced the emphasis on heat and CHP in its final report. The Biofuels Directive is also raising interest in transport fuels.

The related support measures for biomass include market support for electricity through Renewables Obligation (including waste gasification), tax exemptions for transport fuels, and a Range of R & D programmes and capital grant support measures. These consist of:

1) £66MM bio-energy capital grants
2) £29MM energy crops scheme
3) £3.5MM infrastructure scheme
4) £10MM clear skies (domestic)
5) £30MM advanced energy from waste demonstrators
6) £2MM/year DTI R & D plus university funding

The tipping-fee for solid wastes range from £45 to £65/tonne. The higher price is paid for medical wastes. Construction of three large combustion plants should start in the next few months.

The near-term growth in renewable energy is dominated by on- and off-shore wind mills. The barriers for biomass are the same: high investment cost, requirement for long term power purchase agreement (difficult to obtain under RO system), the need for long term fuel supply contracts, and lack of general familiarity with biomass technologies. The additional barriers for BMG include poor reputation of the technology (from ARBRE demonstration), poor evidence of reliability, high purchase cost, lack of mass market to support volume production, the large up-front engineering costs claiming that each project is unique, environmental concerns with discharges to water and air, and the high cost and institutional difficulty to establish grid connection.

Research and development: R & D Work and some related activities are given below:

<u>Biomass Engineering Ltd</u>

1. Three BMG power generation systems are in successful operation
2. Ceramic filter investigation – complete and successful
3. Microturbine – complete and successful
4. Fuel flexibility in Downdrafts – ongoing and successful
5. Process scale-up to a 250KWe CHP units using waste wood from furniture factories in Lancashire

Biomass Engineeriung is now in the process of evaluating ceramic filters from Pall-Schumacher, Tenmat, and Madison Filter Co.,

<u>Exus Energy</u>

1. Commissioning of Blackwater Valley, complete with interesting results
2. Catalytic clean up of IC engine exhaust – complete and successful

<u>Siemens Industrial Turbines, Lincoln</u>

1. Development of gas turbines for biomass gasification applications – in progress
2. Combustion plus high mass flow power turbine technology development in progress
3. Focus on MCV fuel gas applications due to increasing interest from waste pyrolysis sector.

Rural Generation

1. Integration of downdraft gasifier with microturbines – in progress Problems following Bowman insolvency - restructuring to use different turbine and catalytic burner, QU Belfast.
2. The Northern Ireland gasifier is operating successfully for 14 hours per day.

Compact Power

1. Experiments to investigate the effects of preheat on two stage process – in progress.
2. Development of a less expensive biomass version of waste to energy process – in progress

Supergen (Web site http://www.supergen-bioenergy.net)

Aston University as the lead contractor coordinates research at six universities and research institutes, and five industrial partners. Program includes six tasks:

1. Process and techno-economic assessment
2. Fuel specification and matching to conversion
3. Thermal reactor modelling
4. Minimisation of engineering risk
5. Co-firing and co-processing biomass
6. Network of British Biomass and Bio-energy Forum

Current and proposed installations:

Winbeg 1: A 22MWe, FERCO combined cycle gasification plant with Siemens gas turbine is proposed for Devon. The fuel is a mix of energy crops, agricultural and forestry residues. Support comes from £11.5 MM Capital Grant plus Renewable Obligation. The expected start date of 2006 is delayed due to lack of permits and local opposition to build the plant.

Medium-scale 7MWe CHP Rotating Kiln Gasifier in Gloucestershire: The plant will include Eco-tran equipment, reciprocating engines and use agricultural and forestry biomass as feed materials. Revenues will be derived from heat sale to nearby sawmill for drying wood. Support comes from £2MM Capital Grant plus Renewable Obligation. The anticipated start date is in 2006. Although granting permits are delayed, it is anticipated that the project will move ahead.

Small Modular CHP: Ballymena – Biomass Engineering 60kWe plant exceeded 10,000 hours of operation

Lancashire farm – Biomass Engineering 250kWe plant has logged in 4,000 hours of operation

Brook hall – Rural Generation 100kWe plant has exceeded 15, 000 hours of operation.

BEDZED – Exus Energy 100kWe plant, completed 5,000 hours of operation.

Killwaughter - Exus Energy 300kWe plant.

Blackwater Valley - Exus Energy - 200kWe plant.

Compact Power – Bristol: This plant has completed three years of commercial operation on wastes with excellent emissions performance. A new 2MW_e demonstration is planned for next year.

Additional information on the UK Projects is available at :
http://www.dti.gov.uk/publications/, Click on "Browse" then
Energy - New and Renewable: biomass

Day 3: Wednesday, September 28, 2005: HSE Workshop

A summary report is under preparation jointly with European GasNet.

STRUCTURE AND GUIDELINES FOR FUTURE TASK MEETINGS

The Task Members discussed the structure and the general program for the FUTURE semi-annual Task Meetings. The consensus recommendations are given below.

1. All Task members are urged to devote three full days to the Task Meeting. Late arrivals and early departures by Task Members diminish the value of group discussions and they also tend to interrupt the on-going proceedings.
2. In order to engage Task Members in discussion on technical issues and country activities, schedule these discussions along with other Task related matters for the **first day** of a three-day Task Meeting.
3. Day 2 should be set-aside for Task Workshop and Day 3 either for a plant/site visit or continuation of technical discussions, Country Reports and if required to extend the Workshop to a more than 1 day event.
4. In case there is no plant/site visit, the Task Leader should seek the majority concurrence of Task Members to move the Workshop to the 3rd day, so that there is continuity in discussion on matters from Day 1 that could be extended to Day 2.
5. To present detailed **technical** Country reports, allot adequate time and split these reports into 5 for each of the two semi-annual Task Meetings.
6. Develop an agenda with time assignments for all technical presentations and use the balance of time for the remaining 5 Country reports.
7. Plant/site visit is not a necessity for each Task Meeting. Visits should be scheduled primarily to see **new** and **informative** operations.

TASK DELIVERABLES
The reports for Workshops 1, 2, 3 and 4 are now under preparation.

FUTURE TASK MEETINGS
The schedule for the remaining two Task Workshops, for the current triennium, is as follows:

Spring 2006**:** June 5-7. 2006, Workshop on Biomass Gasification Gas Clean-up – Freiberg, Germany

Fall 2006: October 16-18, 2006, Workshop on Biomass Gasification Success Stories and Lessons Learnt, Chicago, IL., and NREL, Golden, CO, USA

The semi-annual task meetings will be held in conjunction with these workshops.

Attachment 1

List of Participants in the HSE Impact of Small-Scale BMG

TASK MEMBERS AND WORKSHOP PARTICIPANTS

1. Eckhard Dinjus, DE
2. Ruedi Buhler, CH
3. Martin Wittrup Hansen, DK
4. Henrik Christiansen, DK
5. Chris Williamson, NZ
6. Suresh Babu, USA
7. Reinhard Rauch, AT
8. Bram van der Drift, NL
9. Emanuelle Scoditti, IT
10. Nick Barker, UK
11. Pekka Simmell, FI
12. Nader Padban, TPS, SE
13. Hermann Hoffbauer, AT

SPEAKERS & CHAIRMEN

1. G. Herdin, GE Jenbacher, Austria
2. B. Schaffernak, Styrian Government, Austria
3. K. Jonsson, Lund University, Sweden
4. L. Cusco, Health and Safety Laboratory, UK
5. H. Timmerer, Technical University, Graz, Austria
6. A.Hofmann, ATB, Austria
7. T.Koch, TK Energie, Denmark
8. H. Knoef, BTG, The Netherlands
9. F. Lettner, Technical University, Graz, Austria
10. E.Oettel, FEE, Germany
11. M. Schaub, CTU/Pyroforce, Switzerland

Attachment 2
IEA Bioenergy Agreement: 2004-2006
Task 33: Thermal Gasification of Biomass
Fall 2005 Meeting
Innsbruck, Austria
September 26-28, 2005
Agenda

Sunday, Sept. 25: Arrive at Hilton Innsbruck Hotel, Salurner Strasse 15, A-6010, Innsbruck, Austria, Tel: +43 (0) 512 59 350, Fax: +43 (0)512 5935220, <www.hilton.com>

Day 1, Monday, September 26: Task Meeting. Location: Hilton Innsbruck Hotel, Salurner Strasse 15, A-6010, Innsbruck, Austria, Tel: +43 (0) 512 59 350,
9:00 AM- Introduction, S.P. Babu
Review and Approve Agenda
Review and Approve Minutes from Spring 2005 Task Meeting, held in Stockholm, Sweden
9:00 AM – Detailed Country Reports

Germany – Eckhard Dinjus, ITC, DE
Austria – R. Rauch, TUV, AT
Denmark – Henrik Christiansen, DEA, DK
European Commission – Maria Fernandez-Guitierrez, EC/Suresh Babu, Task 33
Italy – Emanuelle Scoditti, ENEA, IT
New Zealand – Chris Williamson, Univ. of Canterbury, NZ
Switzerland – Ruedi Buhler, U+E/Serge Biollaz, PSI, CH
Sweden – Nader Padban, TPS, SE
USA – Richard Bain, NREL, USA/Suresh Babu, Task 33
Finland – Pekka Simmell, VTT, FI
The Netherlands - Bram van der Drift, ECN, NL
United Kingdom – Nick Barker, AEAT, UK

(Coffee breaks around 10:30 AM and 3 PM, Lunch at Noon)

5 PM – Wrap-up for the Day
6 PM – Task Dinner

Day 2, Tuesday, September 27: Task Meeting. Location: Hilton Innsbruck Hotel
9:00 AM- Introduction, S.P. Babu

Small-scale Biomass Gasification Systems – Nick Barker, AEAT, UK
(case studies from FI, Pekka Simmell, FI and from China, Emanuele Scoditti, IT – On request)

WS 1 Draft Report on: Short, medium and long term perspectives of biomass gasification technologies, Suresh Babu, Task 33
WS 2 Draft Report on: Gas Cleaning & Gas Engines for Small-scale Applications, Martin Wittrup Hansen, Force Technologies, DK
WS 3 Draft Report on: BMG Synthesis Gas Conversion– Bram van der Drift, ECN, NL

WS 4 (In cooperation with GasNet): Ruedi Buhler, U+E, CH
Special Topics – Henrik Christiansen, DEA, DK (on request)
- Nader Padban, TPS, SE (on request)
- Others

4 PM: Comments, Discussion and Action Items.
Future meetings: WS topic, date, and location.
Spring 2006**:** **WS 5** - June 5-7. 2006, Gas Clean-up – Germany
Fall 2006: **WS 6 –** October 16-18, 2006, Topic: TBD, Location: TBD
(Coffee breaks around 10:30 AM and 3 PM, Lunch at Noon)
5 PM: Adjournment

Day 3, Wednesday, September 28: Task Meeting. Location: Hilton Innsbruck Hotel
8:30 AM to 6 PM: Workshop 4 on Health Safety, and Environmental Impact, Joint workshop with GasNet/ThermalNet (see the second attachment)