98/03897 Fixed-bed pyrolysis of cottonseed cake: product yields and compositions

Putun, A. E. *et al.* *Energy Sources*, 1997, 19, (9), 905–915.

A cottonseed cake sample has been subjected to fixed-bed pyrolysis experiments to determine its potential as a source of renewable fuels and chemical feedstocks. The effects of heating rate, pyrolysis atmosphere and pyrolysis temperature on the product yields and chemical compositions have been investigated. The maximum oil yield of 27% was obtained in N_2 atmosphere at pyrolysis temperature of 550°C and heating rate of 7°C/ min^{-1}. The oil obtained from cottonseed cake was found to be quite similar to the crude oil and shale oil, according to its chemical characterization.

98/03898 Flaming pyrolysis: a novel approach for the production of bio-fuels

Griffiths, A. J. *et al.* *Combust. Emiss. Control III*, 1997, 277–292. Edited by Adams, M., Institute of Energy, London, UK.

Research work undertaken on a 200 kW batch pyrolyser using flaming pyrolysis techniques is reviewed. The paper highlights the design and operational characteristics via the use of a range of feedstocks that include wastes and biomass materials, such as furniture waste, scrap tyres, and manure. The constituents of the biofuel are identified and discussed in relation to char formation. Using a range of boundary conditions, a simulation of this complex process has been carried out to examine more closely the key parameters affecting the performance of the pyrolyser. The results are compared with relevant experimental data.

98/03899 Gasification of biomass wastes and residues for electricity production

Faaji, A. *et al.* *Biomass Bioenergy*, 1997, 12, (6), 387–407.

For Dutch conditions, the technical feasibility and the economic and environmental performance of atmospheric gasification of biomass wastes and residues integrated with a combined cycle for electricity production are investigated. The system selected for study is an atmospheric circulating fluidized bed gasifier combined cycle (ACFBCC) plant based on the General Electric LM 2500 gas turbine and atmospheric gasification technology. The performance of the system is assessed for clean wood, verge grass, organic domestic waste, demolition wood and a wood–sludge mixture as fuel input. An ASPENplus model is used to perform the system calculations. The composition of the fuel-gas was derived by laboratory-scale fuel reactivity tests and subsequent model calculations. The net calculated efficiencies for electricity production are 35.4–40.3% (LHV) for the fuels studied, with potential for further improvement. Environmental performance is expected to meet strict standards for waste incineration in the Netherlands. The system seems flexible enough to process a wide variety of fuels. The kWh costs are very sensitive to the system efficiency but only slightly sensitive to transport distance; this is an argument in favour of large power-scale plants. As a waste treatment option the concept seems very promising. There seem to be no fundamental technical and economic barriers that can hamper implementation of this technology.

98/03900 Gasification process developments offer new opportunities for biomass-to-energy

Menville, R. L., Jr. *Bioenergy '96, Proc. Natl Bioenergy Conf., 7th*, 1996, 1, 289–295.

Operation of the a new commercial scale gasification system (referred to as the 'commercial demonstration module' or 'CDM') constructed by the Brightstar Synfuels Company started in 1996. Located near Baton Rouge, Louisiana, the new plant will be used for demonstrating BSC's proprietary process on customer specific feedstocks and training customer operating personnel. A medium Btu syngas is produced by the BSC's gasifier which uses steam reforming technology in a very efficient and environmentally sound system. A strong demand for such a system exists particularly among forest products companies. The primary market is panel mills which have a large heat requirement, substantial quantities of dry sanderdust available and a desire to improve their emissions profiles. Testing during commissioning and initial operations has concentrated on clean, relatively dry hardwood sawdust to establish baseline data. The syngas produced has a heating value of 300 to 400 Btu/scf.

98/03901 Gasification technologies for heat and power from biomass

Beenackers, A. A. C. M. and Maniatis, K. *Biomass Gasif. Pyrolysis, [Conf.]*, 1997, 24–52. Edited by Kaltschmitt, M. and Bridgwater, A. V., CPL Press, Newbury, UK.

Commercially available biomass gasifier systems or those under development are reviewed. in relation to particular applications, the paper discusses the advantages and possible problem areas in both large- and small-scale technologies. Catalysed by the EC JOULE and AIR programmes, a rather spectacular increase in interest in small scale fixed bed gasification technology, particularly for combined heat and power generation, has been noted. Co-gasification of biomass and coal also attracts interest. Several initiatives are undertaken to raise power from co-combusting producer gas from biomass in conventional power stations. Also combusting producer gas for indirectly heating-up the automotive air for a gas turbine demands attention. Both counter current fixed bed and fluidized bed gasification for heat applications appear to be commercially available. Under development are gas turbine-driven combined heat and power units based on (circulating) fluid bed technology under the EC THERMIE programme at a scale of 10 MW_e. Rapid progress is made in improved gas cleaning technology, particularly also under the JOULE and MR programmes of the European Commission. An increasing number of pilot plant test facilities are available for testing the gasification of difficult fuels in various integrated systems.

98/03902 Greenhouse gas emissions and energy balances in bio-ethanol production and utilization in Brazil (1996)

De Carvalho Macedo, I. *Biomass and Bioenergy*, 1998, 14, (1), 77–81.

Brazilian sugar cane production was 273 million t/year in the 1996/97 season, leading to 13.7 million m^3 ethanol and 13.5 million t of sugar. Greenhouse gas emissions were evaluated for the agronomic industrial production processes and product utilization including N_2O and methane. Up-dating the energy balance from 1985 to 1995 indicated the effect of the main technological trends; fossil fuel consumption due to the increasing agricultural mechanization is, apparently, largely off-set by technological advances in transportation and overall conversion efficiencies (agricultural and industrial). In ethanol, output/input energy ratio grew to 9.2 (average) and 11.2 (best values). Net savings in CO_2 (equivalent) emissions due to ethanol and bagasse substitution for fossil fuels correspond to 46.7×10^6 t CO_2 (equivalent)/year, nearly 20% of all CO_2 emissions from fuels in Brazil. Ethanol alone is responsible for 64% of the net avoided emissions.

98/03903 High-temperature reactions of straw ash and the anti-sintering additives kaolin and dolomite

Steenari, B.-M. and Lindqvist, O. *Biomass and Bioenergy*, 1998, 14, (1), 67–76.

With respect to the formation of crystalline compounds and high-temperature reactions in ash, as well as sintering and melting behaviour, straw from various types of rape, wheat and barley has been the subject of this study. Full results are presented.

98/03904 Horse dung as a partial substitute for cattle dung for operating family-size biogas plants in a hilly region

Kalia, A. K. and Singh, S. P. *Bioresource Technology*, 1998, 64, (1), 63–66.

Over a 12-week period, biomethanation of horse mixed with cattle dung in the ratios 0:1, 1:4, 2:3, 1:1, 3:2 (wet wt/wt) was carried out in three litre digesters for at 25±1°C. These mixtures produced 2.7, 4.1, 4.7 and 4.4% less biogas, respectively, than the 29.51 biogas kg^{-1} obtained from a digester containing pure cattle dung. A tendency for solid–liquid separation with increase in horse dung percentage was also experienced. A one year comparative field study on a 2 m^3 biogas plant run on a 1:4 mixture of horse and cattle dung and a 1 m^3 biogas plant run on pure cattle dung gave average daily gas productions of 21.9 m^3 and 22.6 m^3 biogas kg^{-1} wet substrate fed, respectively, was carried out. It revealed that 20% replacement of cattle dung can be made by horse dung for operating family-size biogas plants without much reduction in their gas production or encountering any operational problem.

98/03905 Life cycle analysis of N_2O emissions from different energy crops

Stelzer, T. *et al.* *Ber. Bergische Univ., Gesamthochsch. Wuppertal, Fachbereich 9, Phys. Chem.*, 1997, (41), 177–187.

For various biogenic energy carriers life cycle analyses were carried out with regard to N_2O release. Carbon dioxide and methane releases were also estimated and added to N_2O emissions to assess the global warming potential (GWP) as carbon dioxide equivalents. Sensitivity analyses were used to evaluate the influence of different boundary conditions like N_2O emission factors from soils and the type of substituted fossil energy carrier. The use of biological energy carriers generally leads to a decrease of GWP, but higher N_2O release and ozone depletion potential as compared to the fossil counterparts. For all biological energy options, release from agricultural soils, fertilizer production, and final combustion dominate the N_2O release. For the fossil counterparts, combustion is the only important N_2O source. Solid biological energy carriers, especially perennial crops, represent more effective substitutes for fossil energy than the biofuel options with regard to the specific GWP and the specific demand for finite primary energy.

98/03906 A method of disrupting fibrous biomass by treatment with a gas

Adamsen, A. P. S. PCT Int. Appl. WO 97 07,688 (Cl. A23K1/14), 6 Mar 1997, DK Appl. 95/965, 30 Aug 1995, 11 pp.

The paper discloses a method for the dry disruption of fibrous biomass. In this method, the biomass is fed through a pressure-tight inlet device into one end of an oblong pressure vessel to be treated herein with an easily liquefiable gas or carbon dioxide under pressure in order to make the biomass absorb the gas in liquid form. The biomass is advanced in the pressure vessel and discharged through a pressure-tight discharge device at its opposite end so that the biogas is depressurized quickly in order to make the gas absorbed in the biomass evaporate rapidly.

98/03907 Municipal solid waste and wood residue utilization via air gasification & hydrocarbon synthesis

Golam, S. and Hurme, M. *Proc. Int. Conf. Solid Waste Technol. Manage.*, 1997, 13, (2), Paper 7A/1, 1–8.

This solid waste utilization process involves the thermochemical conversion of wood residue and municipal solid waste to liquid fuels. Air is used as a gasifying agent in the gasification of solid wastes to form a producer gas and liquid fuels are produced from the producer gas via hydrocarbon synthesis.

The thermochemical process alternatives for the production of liquid fuels from biomass/solid waste are assessed and air and oxygen gasification concepts are compared. The air gasification option seems economically attractive. The authors put forward a proposal for a treatment process of 1 kton/day of solid waste for the production of liquid fuels. The technical and economic assessment shows that the process is technically feasible for solid waste utilization and appears to be more economically attractive than the processes using other solid feedstocks such as coal and wood.

98/03908 Opportunities for fast pyrolysis in small-scale electricity generation

Toft, A. J. and Bridgwater, A. V. *Dev. Thermochem. Biomass Convers.*, 1997, 2, 1556–1566. Edited by Bridgwater, A. V. and Boocock, D. G. B., Blackie, London, UK.

With the aim of improving the low efficiency, capital intensive steam turbine cycles that are currently used for electricity generation, various systems have been suggested using biomass. While the integrated gasification combined cycle system using gas turbines has been favoured on a large scale, diesel engine systems are more suitable at smaller scales because their investment costs and efficiencies are less sensitive to scale. Diesel engines could be driven by liquids produced in fast pyrolysis. Models have been developed that calculate the costs of producing electricity from biomass via fast pyrolysis and diesel engines. It is expected that such systems would compete with atmospheric gasification and diesel engine systems and these systems have also been evaluated for comparison. Initial analyses have shown that electricity production costs are very similar for the two systems where the conversion (fast pyrolysis or gasification) stage is directly connected to the generating stage. However, fast pyrolysis may be decoupled from the generator and this could give pyrolysis an advantage over gasification. Three de-coupling options are assessed in this paper to evaluate how de-coupling could be used to improve the economics of fast pyrolysis and hence increase the opportunities for small-scale electricity generation application.

98/03909 Options for thermochemical processing of biomass

Spath, P. and Tyndail, D. *Proc. Biomass Conf. Am.: Energy, Environ., Agric. Ind., 2nd*, 1995, 607–616.

Biomass is converted to transportation fuels and fuel additives such as methanol, mixed alcohols, hydrogen, ethers, gasoline, diesel and jet fuel via thermochemical processing. These products are produced by thermochemical technologies involving gasification or pyrolysis of biomass. A synthesis gas consisting primarily of hydrogen, carbon monoxide, carbon dioxide and water is produced by gasification technology. This gas can be used to make a wide range of products including alcohols, hydrogen and hydrocarbon fuels. Pyrolysis technology involves pyrolysis of biomass to produce high molecular weight pyrolysis vapours that can be converted into either a refinery feedstock or a thermobiodiesel product. At the National Renewable Energy Laboratory, standalone biomass systems, as well as the integration of biomass thermochemical conversion technology with existing facilities, are being examined. Possibilities exist for integrating with petroleum refineries, natural gas-to-methanol plants, ethanol plants, coal gasification facilities, and pulp and paper mills.

98/03910 Performance and economics of power from biomass

Solantausta, Y. *et al. Dev. Thermochem. Biomass Convers.*, 1997, 2, 1539–1555. Edited by Bridgwater, A. V. and Boocock, D. G. B., Blackie, London, UK.

Performance and economic evaluations have been conducted on advanced biomass power production technologies as part of the International Energy Agency (IEA) Bioenergy. Models—AspenPlus and GateCycle, developed by the IEA working group—were used to determine performance and to evaluate the cost of new concepts. Several plant configurations based on gasification and pyrolysis processes with diesel engines, gas turbines, and steam turbines were analysed at 5–60 MW_e capacities. The study included both technical sensitivities and economic sensitivities. Compared to conventional steam cycle power plants, the new systems generally have higher efficiencies. Present commercial applications are generally limited to special cases where biomass residues are available, or when combined heat and power production is viable. It is difficult to commercialize biomass technologies on larger scale (e.g. IGCC) in spite of favourable economics, due to the large scale needed for demonstration, which results in a large investment and a high risk for developers. Development of power production based on pyrolysis systems may be feasible, as it appears viable in small niche projects.

98/03911 Plant for cogeneration with grape-stone residues

Poveda Ciorraga, M. and Poveda Bautista, R. *Energia*, 1997, 23, (1), 77–80. (In Spanish)

The paper experimentally demonstrates the possibility of using grape processing residue biomass as fuel in thermal power station. The paper considers the physicochemical aspects of the combustion process and the impact of the gaseous and solid combustion products on the environment.

98/03912 Procedure for utilization of used wood

Auerbach, H. J. *et al.* Ger. Offen. DE 19,637,909 (Cl. C08J11/00), 19 Mar 1998, Appl. 19,637,909, 18 Sep 1996, 18 pp. (In German)

The used wood is mechanical treated to remove metals and other inorganic materials. Then cellulose is separated from the lignin, the lignin is upgraded or discarded and wood sugar is recovered and fermented to yield ethanol and residues. The residues are anaerobically fermented to yield biogas and the ethanol, biogas and biofuels are used as energy sources.

98/03913 Pyrolysis of wet cellulose containing biomass to produce hydrogen

Yokoyama, S.-y. *et al.* Brit. UK Pat. Appl. GB 2,310,865 (Cl. C10J3/00), 10 Sep 1997, JP Appl. 96/64,304, 21 Mar 1996, 14 pp.

Containing biomass, water and a metal catalyst, a cellulose was fed into a reactor to form a liquid phase. The heating medium within a jacket raises the temperature of the reactor to between 250–374°C. Inert gas is preferably fed into the upper fraction of the reaction vessel to maintain a pressure higher than the saturated vapour pressure of water for collection of hydrogen. Alternatively, inert gas may be fed into the bottom of reaction vessel to sweep formed hydrogen into upper space. Collected gas may then be discharged to gas separation units.

98/03914 Tar yield and collection from the pyrolysis of large biomass particles

Miller, R. S. and Bellan, J. *Combust. Sci. Technol.*, 1997, 127, (1–6), 97–118.

Using the model of Miller and Bellan (1997), the tar yield collection from the pyrolysis of relatively large particles of biomass were investigated. The ratios of cellulose, hemicellulose, and lignin within the biomass were varied, to consider a variety of feedstocks. The effects of secondary tar reactions, quenching, temperature, particle size and carrier gas were assessed. Secondary tar reactions occurring in both the particle's interior and the exterior boundary layer strongly reduce the potential amount of tar available for collection compared to the maximum given by kinetic predictions. The existence of an optimal reactor temperature range for maximizing tar yields is the primary effect of these reactions. This range is a function of both the quenching location and the initial particle size. For rapid quenching near the particle surface, tar collection is maximized at high temperatures for small particles, and at low temperatures for large particles. For delayed quenching, low temperatures slow the secondary reactions and provide larger tar yields for all particle sizes investigated. The choice of the inert carrier gas also determines the char yields; primarily due to changes in heat capacity. In order to assess the influence of the biomass apparent density, thermal conductivity, heat capacity and primary heats of reaction, a sensitivity study has been performed.

98/03915 Technoeconomic analysis and life cycle assessment of an integrated biomass gasification combined cycle system

Mann, M. K. and Spath, P. L. *Dev. Thermochem. Biomass Convers.*, 1997, 2, 1567–1581. Edited by Bridgwater, A. V. and Boocock, D. G. B., Blackie, London, UK.

The environmental impacts of all processes used in transforming a raw material to a final product are quantified with life cycle assessment. When performed in conjunction with a techno-economic feasibility study, it is possible to quantify the total economic and environmental benefits and drawbacks of a process. In addition, life cycle assessment can distinguish between truly environmentally friendly processes which either mitigate or eliminate upstream emissions and energy consumption and those that are only environmentally conscious in their final production step. A biomass gasification combined-cycle power plant, consisting of a low pressure indirectly-heated gasifier integrated with an industrial gas turbine, was simulated using ASPEN Plus computer programme. Economic analyses were then performed to determine the levelled cost of electricity. The economic viability and efficiency of power production from this system appear quite attractive, with the cost of electricity near the competitive range of current electricity prices in the United States of America. A life cycle assessment is also being performed to quantify the total benefits and drawbacks of the entire system from biomass crops through power distribution.

98/03916 Use of biogas in the public natural gas network, illustrated by the example of Compogas deliveries at Samstagern, Switzerland

Weber, J. C. *Gas, Wasser, Abwasser*, 1998, 78, (2), 79–83. (In German)

In the Compogas facility, green (agricultural) waste is fermented to compost and biogas, processed to comply with natural gas quality standards, which is fed into the Zurich municipal gas supply network.

98/03917 The use of LCV gas from biomass gasifiers in, internal combustion engines

Stassen, H. E. and Koele, H. J. *Biomass Gasif. Pyrolysis, [Conf.]*, 1997, 269–281. Edited by Kaltschmitt, M. and Bridgwater, A. V., CPL Press, Newbury, UK.

Depending on the chemical composition and moisture content of the fuel as well as on the efficiency of the gasification reactor, the biomass gasifiers produce a LCV-gas with a lower heating value in the range of 4500–6000 kJ/nm^3. The use of such fuel gas in internal combustion engines generally results in derating the maximum power output of such engines. The paper