Project summary

(February 2012)

Project acronym:	Bioliquids-CHP
Project name:	Engine and turbine combustion for combined heat and power production
Call:	FP7-ENERGY-2008-RUSSIA
Activity code:	ENERGY.2008.2.2.1: Enhancing strategic international cooperation with Russia in the field of power generation from biomass
Keywords:	Cooperation with Russia in the field of power generation from biomass; combustion, bio-liquids, engine, turbine, combined heat and power (CHP), cogeneration
Duration:	January 2009 – December 2011 (36 months)
Total cost:	4,309,696 Euros
Commission funding[1]:	1,602,319 Euros
Project website:	www.bioliquids-chp.eu

Project partners:

- BTG Biomass Technology Group BV (NL)
- EnConTech BV (NL)
- University of Florence, CREAR (Italy)
- Boreskov Institute of Catalysis, Siberian Branch of Russian Academy of Sciences (Russia)
- Federal State Unitary Enterprise 'Central Scientific Research Automobile and Automotive Engines Institute' - FSUE 'NAMI' (Russia)
- Aston University (United Kingdom)
- The Likhachev Plant (AMO ZIL) (Russia)

Project management

Overall coordination:
John Vos
BTG Biomass Technology Group BV
Tel. +31-53-486 1186
Email: vos@btgworld.com

Technical issues:
Bert van de Beld
BTG Biomass Technology Group BV
Tel. +31-53-486 2288
Email: vandebeld@btgworld.com

Project Context

Whereas the EC had set the target to increase the share of combined heat and power (CHP) in the European energy supply to 18% by 2010, CHP currently accounts for only 11% of it[2], and substantial efforts remain to be done. Biomass CHP could greatly contribute to the effort needed and account for 44% of CHP in Europe by 2050[2]. Small-scale (50 to 1000 kW_e), direct biomass-to-

[1] In addition, 72 million Rubles are made available by the Ministry of Education and Science of the Russian Federation.

[2] Source: www.cogeneurope.eu

electricity CHP-systems could contribute to this potential, particularly in remote regions. However, the implementation of such systems has been rather limited for different reasons, including:

- Relatively high investment costs for small-scale systems
- High running costs
- Poor reliability and availability
- Low acceptance by end-users

The factors causing these intrinsic problems are manifold, but main causes include:

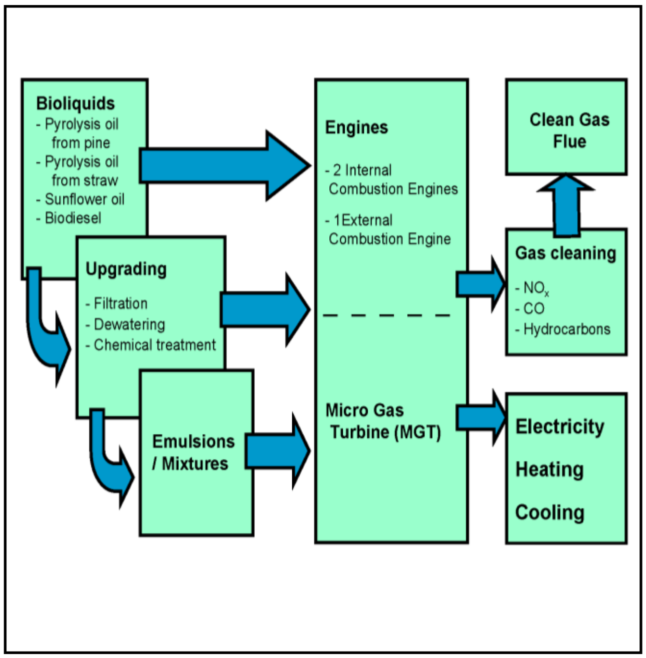
- The presence of contaminants in the biomass (apart from ash, oxygen and water can also be considered this way)
- The limited availability of uniform types of biomass
- The non-uniform appearance of biomass
- Its general low energetic density (especially in terms of GJ/m^3), requiring huge volumes of biomass stocks to be stored near the electricity production unit

Converting biomass into bioliquids[3] can solve these problems in different ways. Amongst others, it increases the acceptance by end-users, as they are uniform and easier to use. Also, the energetic density of bioliquids is higher than that of the biomass used to produce them. The Bioliquids-CHP project was set up to break down the technical barriers preventing the use of bioliquids in engines and turbines.

Project objectives

The aim of the project is to adapt engines/turbines to enable operation on a variety of bioliquids, including pyrolysis liquids.

On the one hand, the project is modifying the design of three different engines and a micro gas turbine so that these can run efficiently on bioliquids such as biodiesel, vegetable oil and pyrolysis oil. On the other hand, bioliquids will be upgraded and blended in order to facilitate their use in engines and turbines. Thus, the most economic and reliable engine/turbine-bioliquids combinations will be developed in order to make the system attractive. In addition, the project is developing methods and techniques to control exhaust emissions (NO_x, CO, particulates), which will improve the environmental sustainability of the engine/turbine-bioliquids combinations.



Bioliquids-CHP project overview

Project progress and way forward

Project progress

The project has been completed, and in line with its objectives considerable progress has been achieved with regards to (a) bioliquids upgrading, (b) modifications of prime movers (engines and turbine) to enable the efficient use of bioliquids, (c) pollutants emission reduction, and (d) the techno-economic and environmental assessment of the developed systems.

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[3] Bioliquids are defined as liquids fuels produced from biomass and used for energy purposes other than transport. Their energy purposes include electricity production, heating and cooling.

Regarding the research on bioliquids, several fuel batches have been produced or purchased, characterised and upgraded. These bioliquids include pyrolysis oil made from pine and straw, straight vegetable oil (i.e. sunflower oil), and biodiesel. The obtained bioliquids have been characterised and their ageing behaviour was monitored. Research activities focused on upgrading PO and on preparing blends or emulsions that can be used in engines/turbine. For pyrolysis oil, different upgrading approaches have been investigated including (a) partial dewatering and fractionation, (b) solids removal in a centrifuge, (c) esterification of acidic components with alcohol, and (d) mild hydrodeoxygenation under elevated pressure in the presence of hydrogen and a catalyst. .

An additional approach investigated by Aston University is the production of tertiary blends. They succeeded in producing a stable blend of pyrolysis oil, biodiesel and alcohol, and a patent for the blending concept was applied for. With regard to pyrolysis oil emulsions, a recipe for its preparation was developed by the University of Florence. The recipe was first used to produce samples at lab scale (few hundred grams) and -when proven effective- scaled-up. The emulsion tested in the engine consisted of pyrolysis oil, 5 wt% of biodiesel and 0.25wt% of emulsifier (Athlox). All bioliquids produced have been fully characterised.

As far as the research on the engines/turbine is concerned, work initially focused on identifying and implementing modifications that would enable the use of bioliquids. The engines/turbine considered in the project include two internal combustion (IC) engines, a newly developed external combustion engine and a micro gas turbine (MGT).

The first IC engine is a Jiang Dong 1-cylinder 20-kW_e diesel engine. BTG first ran preliminary tests with diesel oil, biodiesel, sunflower oil, ethanol and pyrolysis oil, and characterised the engine. They then identified the required modifications and suitable materials to manufacture pyrolysis oil resistant engine parts. In the last project year BTG implemented an extensive programme to understand the combustion behaviour of a range of test fuels and to steer further development and modifications. A significant achievement was the operation of the engine for 40 hrs on pure pyrolysis oil without any change of fuel pump or injector, and without significant effect on the flue gas emissions. Similar results could not be found in literature.

The second IC engine is a Russian YMZ-238M2 unit, that was modified by NAMI. This engine was assembled on a test bench with a generator, an exhaust gas cleaning system, a heat unit and a microprocessor control system; and extensive testing of the resulting CHP plant has been completed. The exhaust gas cleaning system consists of a syngas reactor and DeNox, both developed by project partner BIC. For this purpose, extensive catalyst research was carried out in the first two years of the project to identify and select the most suitable catalysts.

The third partner working on engines is Encontech. They focused on the development and modification of a Rankine-cycle engine and a Stirling/Manson-type single-piston external combustion engine. First individual engine components were improved and tested, and later the complete engines. The improvements resulted in an unparalleled versatile new heat engine (Encontech’s third engine), which can use any heat source (including a variety of bioliquids) from 50 to 1000 ^{o}C and is easy scalable in the range 1-1000 kW_e per cylinder.

The last prime mover considered in the project is a Garrett GTP 30-67 micro gas turbine operated by the University of Florence.. First, the turbine was adapted with minor modifications for vegetable oil and biodiesel, and characterised using diesel oil. In addition, three-dimensional computational fluid dynamic simulations were carried out on the MGT combustor to assess the major modifications required for biofuels feeding. This work led to a modified design of the combustor chamber for bioliquids fuelling, and in 2011 a new, enlarged combustion chamber was installed on the turbine. Testing with biodiesel and vegetable oil showed a reduction in flue gas emissions, and the modification is considered successful. Unfortunately, test runs with pyrolysis oil were not successful so far mainly due to stability problems with the oil feeding pump.

In addition to newly developing or modifying prime movers, the project assessed the developed systems in terms of economic and environmental performance, and identified different market opportunities for prospective users of the developed systems. In 2011 Aston University refined, updated and finalised a document discussing the performance and cost estimates for biomass CHP technologies as well as their environmental impacts. They prepared a partial database of prime movers using bioliquids in CHP mode in Italy, The Netherlands and the United Kingdom. The developed economic model for economic evaluation, sensitivity analysis and case studies was updated with additions in the background data, input, results presentation and evaluated scenarios..

Last but not least, project results were regularly presented at conferences and made available at the project website. Special achievements in 2011 were the organisation of final dissemination event in Brussels in November 2011, the publication at the website of a comprehensive set of training and education materials on bioliquids -in particular pyrolysis oil- targeted to Master students, and the preparation and production of several peer-reviewed articles.

Expected results of the project
Strategic results of the project include:

- PO upgrading processes.
- PO-bioliquids emulsions/blending processes.
- Bioliquid internal combustion engine concepts.
- Bioliquid external combustion engine concept.
- Bioliquid MGT turbine concept.
- Exhaust gas cleaning system for bioliquid engines.
- Techno-economic and environmental assessment of the developed systems.

Expected impacts of the project
Strategic impacts of the project include:

- Increase in electricity production from biomass by reducing upgraded pyrolysis oil production prices and by improving bioliquid quality.
- Reduction of costs of electricity production from biomass.
- Optimisation of the engine-bioliquid fuel combination.
- Adaptation of existing technologies (Bioliquid production, engines/turbines and CHP-units) with a view to optimise the engine-fuel combination.
- Improvement of the environment, the quality of life, health and safety.
- Job creation.

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