Bioliquids-CHP
Power generation from Biomass

# Partner – Aston University, Bioenergy Research Group

Aston University
Birmingham

## CONTRIBUTIONS TO PROJECT

**Techno-economic and environmental assessment** of CHP technologies up to 1 MWe including comparisons with other heat and power technologies.

Creation of a database of biomass based CHP systems.

**Production of blends of fast pyrolysis liquid with biodiesel and bio-alcohols** for testing on engines and microturbines.

**Analysis of fast pyrolysis and other bioliquids** to support the testing of bioliquids and blends.

**Awareness and dissemination plan** for outputs from the project to publicise the project and results.

**Exploitation plan** for outputs from the project to accelerate the rate and success of key project results.

## MAIN CONTACT


Prof. Tony Bridgwater
Tel: +44 121 204 3381
Fax: +44 121 204 3680
Email: a.v.bridgwater@aston.ac.uk

Bioenergy Research Group
Aston University
Aston Triangle
Birmingham B4 7ET
UK


## EXPERIENCE AND FACILITIES

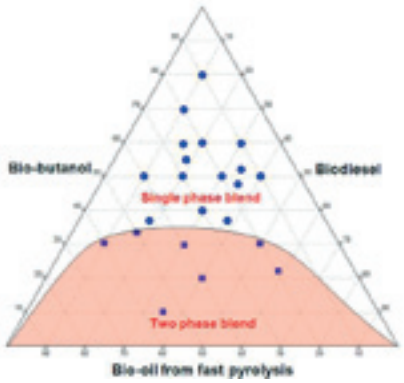
**Aston University Bioenergy Research Group (BERG) was formed to focus research in bioenergy. It is the largest academic research group in bioenergy in the world.**

Over £20 million of funding has been won for Aston University from a variety of sources including the European Commission, EPSRC, UK government and industry and international organisations. The most significant current activity is leadership of the SUPERGEN Bioenergy Consortium for a second term of 4 years to 2011.

In addition there are a number of major European projects including a large infrastructure project – BRISK - in which Aston is playing a core role; and a substantial EC sponsored collaborative project with Latin America - Dibanet. Further major contributions to the subject area have been in the organisation and chairmanship of international conferences including the peer reviewed series on thermochemical biomass conversion in 1988, 1992, 1996, 2000 and 2004.

## ACHIEVEMENTS AND OUTCOMES

A database of biomass based CHP units has been created for the Netherlands and the United Kingdom. The data includes unit electrical capacity, location, fuel and prime mover costs and other data when available.




A number of techno-economic assessments of various CHP systems were carried out for each of the partner countries. This is based on a model which was built to generate performance and cost estimates with minimal user input, using typical values and evaluations programmed into the model. The assessment basis is estimation of the Internal Rate of Return, as well as the heat and power production costs. Different fuel price scenarios were modelled and a variety of prime movers, such as internal combustion engines, turbines, ORC and Stirling engines were included in the evaluation. A comparison study using different fuels was carried out, including conventional diesel and natural gas.

An environmental assessment for the UK was carried out using the Biomass Environment Assessment Tool (BEAT V2), which provides a standard model that can be used to work through different case studies and enable comparisons among them.

New developments in blends of pyrolysis oil with biodiesel and bio-alcohols have been achieved and the concept was nominated among the best 10 ideas in the Cleantech Open UK competition. The most important feature of this achievement is the ability to tailor the blend to the end user requirements, thus the blend could target a specific heating value, viscosity or flash point if required.

# Partner – Boreskov Institute of Catalysis of the Siberian Branch of the Russian Academy of Sciences (BIC)

## CONTRIBUTIONS TO PROJECT

**Catalyst development and testing for pyrolysis oil upgrading.**

**Catalyst and reactor development for diesel oil and bio-oil ATR conversion in synthesis gas.**

**Catalyst research and screening for De-NOx.**

**Testing of selected ATR and De-NOx catalysts.**

**Catalyst manufacturing and exhaust gas cleaning system development.**

**Participation in diesel engine and exhaust gas cleaning system testing.**

## EXPERIENCE AND FACILITIES

**With more than 1000 staff, BIC is the largest specialized catalysis institute worldwide; carrying out fundamental and applied catalysis investigations. It is experienced in the preparation and testing of catalysts, and in developing chemical reactors for: synthesis gas generation by steam conversion; autothermal reforming (ATR) and partial oxidation; hydrogen production from syngas; methanol and DME synthesis from syngas; and biofuel upgrading.**

BIC's scope of work ranges from fundamental problems of catalysis, to the design of new catalytic processes and industrial-scale catalyst production. It also performs studies on fundamental catalysis, including studies of catalyst structure and formation mechanisms; kinetic studies and mathematic modelling of catalytic processes.

Its potential for applied catalysis enables the development of:

- the next generation highly-efficient catalysts for chemical industry and oil processing;
- catalysts and technologies for new application areas;
- new catalytic systems and processes for the synthesis and composites with predetermined properties;
- catalysts and technologies for detoxification of process wastes.

## ACHIEVEMENTS AND OUTCOMES

Several catalyst composites have been developed based on reinforced gauze and metal porous support for the autothermal conversion of diesel and biodiesel fuels, and also for the steam reforming of biofuel mixtures and pyrolysis oil. The developed catalysts were tested during short-term (several hours) and long-term tests.

The optimal conditions for maximizing the syngas yield from diesel have been defined which yield 2.88 Nl of hydrogen and carbon monoxide per g of diesel; and 18 mole hydrogen per mole of diesel. Similarly optimum conditions for biodiesel conversion have been defined which yields 1.8-2.0 Nl per g biodiesel; and from pyrolysis oil, yields of up to 62% hydrogen have been achieved.

Effective DeNOx catalysts for operation over a wide temperature range have been developed based on silver on alumina and the conditions for successful operation have been well characterized.

## MAIN CONTACT

Prof. Valeriy A. Kirillov
Tel: + 7 383 330 61 87
Fax: + 7 383 330 61 87
Email: vak@catalysis.ru

Boreskov Institute of Catalysis of the Siberian Branch of the Russian Academy of Sciences (BIC)
630090
Lavtentieva street, bld. 5
Novosibirsk
Russia

# Partner – BTG Biomass Technology Group BV

## CONTRIBUTIONS TO PROJECT

**Production of fast pyrolysis liquids** for testing in engines and blending with other bioliquids.

**Analysis of fast pyrolysis liquids** to support the testing of bioliquids and blends.

**Upgrading of fast pyrolysis liquids** to improve their properties with respect to direct combustion in an engine or turbine, and to making blends and emulsions. Upgrading activities include filtration, dewatering, mild treatment, catalytic pyrolysis, production of blends and emulsions.

**Development of engine components** that are tolerant to bioliquids mixtures and upgraded oil.

**Project coordination**

**Project dissemination and exploitation**

## MAIN CONTACT

Dr. Bert van de Beld
Tel: +31 53 486 2288
Fax: +31 53 486 1180
Email: vandebeld@btgworld.com

BTG Biomass Technology Group BV
Josink Esweg 34
7545 PN, Enschede
The Netherlands

## EXPERIENCE AND FACILITIES

**BTG Biomass Technology Group BV is a SME, which for the past 30 years has specialised in the conversion of biomass into biofuels and bioenergy. BTG's two business units, Consultancy and Research and Technology Development (RTD), work in synergy and ensure innovative and commercially feasible activities.**

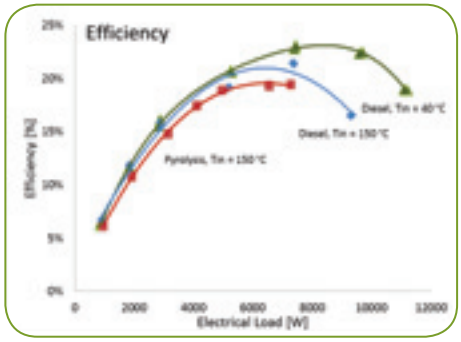
BTG started its fast pyrolysis developments in the 90's with a new reactor concept, which has been continuously optimised in its dedicated research lab where several test facilities are available. BTG fast pyrolysis developments have resulted in several patents, which are now commercially exploited by its daughter company BTG-BTL.

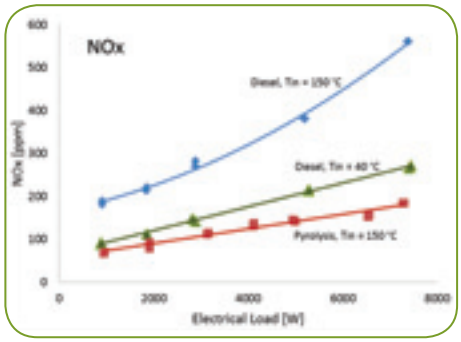
BTG has extensive experience and is deeply involved in European bioenergy research and development (R&D) programmes, as it is or was project co-ordinator or partner of various biomass pyrolysis R&D projects since the Fourth Framework Programme.

## ACHIEVEMENTS AND OUTCOMES

Pyrolysis oil has been produced from pine and straw, and distributed among the partners. Solids were removed by application of a centrifuge.

A standard diesel engine has been modified to enable the fuelling of pyrolysis oil. The fuel pump and fuel injector have been constructed in-house from stainless steel to withstand corrosion. To achieve sufficient fast ignition and combustion of the pyrolysis oil the incoming air is preheated to 150°C. Additionally, it is possible to change the fuel injection timing. A successful continuous run of 12 hours has been carried out without a notable change on performance and emissions. In comparison to mineral diesel fuel, wood-derived pyrolysis oil resulted in higher CO and lower $NO_x$ emissions.



# Partner – CREAR – Research Center for Renewable Energy

C.R.E.A.R. CENTRO RICERCA ENERGIE ALTERNATIVE E RINNOVABILI

## CONTRIBUTIONS TO PROJECT

**Education & training:** activities dedicated to students and technicians, addressing the research issues investigated during the Bioliquids-CHP project.

**Gas turbine adaptation and testing:** Compared to internal combustion engines, CHP units based on micro gas turbines (MGT) offer several advantages, among which the compactness, the high power-to-weight ratio, the lower pollutant emissions and maintenance costs. Depending on the specific type of gas turbine, also fuel flexibility could be better than diesel engines, as the fuel is continuously burnt in a hot environment and there is not possible mixing among fuel and lubricating oil.

**Pyrolysis oil upgrading:** among various options, emulsification is a possible method to improve the chemical-physical characteristics of pyrolysis oil. CREAR investigates this technique in close collaboration with CSGI (Centre for Colloid and Surface Science).

## EXPERIENCE AND FACILITIES

**CREAR, directed by Prof. Ing. F Martelli, merges several Departments of the University of Florence into a single multidisciplinary research body (led by the Energy Engineering Department). Through its members, CREAR is active in biomass and bioenergy research, as well as on other renewable energies, and currently coordinates and participates in several EU and national supported projects.**

Research work is undertaken in the field of biomass production; lignocellulosic bioethanol (e.g. lignin rich stream energy valorization); small scale biomass power plants (either combustion, pyrolysis or gasification based), pure and reconstructed (esterified) vegetable oils; and algae biofuels (technologies for algae cultivation and energy conversion).

CREAR is involved with various national and international renewable energy organisations including EABA (European Algae Biomass Association); ISES-Italia (Italian Section of the International Solar Energy Society.); IEA-Bioenergy (International Energy Agency); SIBA (Italian Society of Bioenergy and Agroindustry), as well as the EU and Italian platforms on biofuels. CREAR recently funded the “Renewable Energy COnsortium for R&D” (RE-CORD), a private-public not-for-profit research Institution operating various bioenergy plants as well as a chemical laboratory fully dedicated to bioenergy and biofuels.

## ACHIEVEMENTS AND OUTCOMES

Emulsions were produced in sufficient amount for laboratory analysis and testing in engines and MGT. Emulsification was found to be a suitable low-cost approach for biomass pyrolysis oil upgrading. Nevertheless, the quality of the resulting bioliquid is still very far from standard fossil fuels quality specification, and its use requires modification of the energy generation technology.

A MGT equipped with a can-type combustion chamber was converted to operate on bioliquids. This type of MGT was chosen as annular combustion chambers are more difficult to be adapted to the variable physical/chemical characteristics of bioliquids. An in-house test bench was designed, engineered, instrumented and built: biodiesel and vegetable oil required minor modifications, while for pyrolysis oil the entire fuel line and the combustion chamber and liner were redesigned and built. The MGT was successfully operated with all the bioliquids under investigation: future work should address long-term operation of the system.

## MAIN CONTACT

Dr. David Chiaramonti
Tel: +39 055 4796 436
Fax: +39 055 4796 342
Email: david.chiaramonti@unifi.it

CREAR
University of Florence
c/o Department of Energetics ‘S.Stecco’
Via S.Marta 3
50139 Florence
Italy

# Partner – Encontech B.V.

Encontech B.V.

## CONTRIBUTIONS TO PROJECT

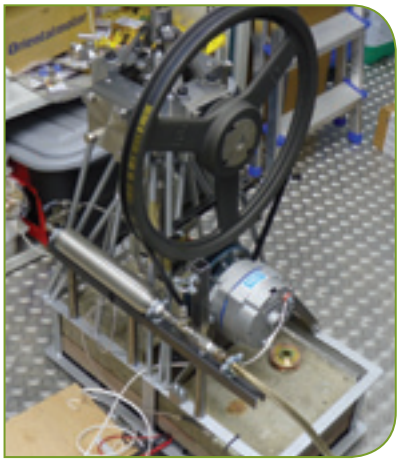
**Liaison between European and Russian project partners.**

**Development of novel external combustion engines for combined heat and power production.**

The engines are coupled with an alternator and can be fuelled with pyrolysis oil. The development includes:

- design and construction of the engines and experimental facilities for their testing;
- experimental and theoretical study of the engines.

The engines are expected to be valuable alternatives to conventional prime movers.



## EXPERIENCE AND FACILITIES

**Established in 2008 as a spin-off of the University of Twente, Encontech BV is a high-tech company, engaged in the research and development of the invented chemical reactors and prime movers.**

The highly innovative reactors, known as pulsed compression reactors, are based on the principle of compressive heating and subsequent expansive cooling, and allow chemical reactions at plasma chemistry temperatures and very high pressure in a very energy efficient way. During the next five years (2011-2016), the company aims to breakthrough the most energy and capital intensive processes in chemical and fuel industries and prime movers.

The development of prime movers for combined heat and power production (CHP) systems in micro and small power ranges is based on the experience accumulated during the reactor development.

## ACHIEVEMENTS AND OUTCOMES

Two types of external combustion engines – “Stirling cycle” engine and Rankine cycle engine - for CHP systems were designed, constructed and tested. Both engines can operate on bioliquids and are expected to be valuable alternatives to conventional prime movers.

The “Stirling type” engine is based on Manson cycle. The engine has only one moving part, no rubbing parts and combines most of the advantages of the newest external combustion engines. The engine constructed has inner diameter of 20 mm and a piston stroke of 40 mm. The pressure of working fluid can be as high as 100 bar. The expected energy efficiency of this engine is about 30% with power of a few hundred Watts at the pressure of working fluid 20 bar and the temperature ratio 3.

The piston of the Rankine cycle engine is driven by compressed gas in the same way as pistons in steam engines. The engine has no oil lubrication, using a crank gear with a straight line mechanism instead; linear motion of the piston is maintained by a gas bearing; the piston itself plays the role of a slide valve delivering a working fluid to the cylinder. The engine covers applications not suitable for the Stirling type engines. It can also be used as a bottoming heat utilizing device to run on heat from exhaust gases of different engines with temperatures from 70°C. The engine constructed has an inner diameter of 40 mm and a piston stroke of 40 mm. In the tests performed the engine was driven by compressed air at pressure up to 20 bar. The measured power output was about 200W.

Some progress has been made to contributing a very great improvement in heat engines. A radically new engine is expected to be ready for demonstration in November 2011.

## MAIN CONTACT

Dr. ir. Alexander Kronberg
Tel: +31 53 489 1088
Fax: +31 53 489 3663
Email: a.e.kronberg@ctw.utwente.nl

Encontech B.V.
Drienerlolaaan 5
7522 NB Enschede
The Netherlands

Bioliquids-CHP
Power generation from Biomass

# Partner – Federal State Unitary Enterprise 'Central Scientific Research Automobile and Automotive Engines Institute' FSUE NAMI

## CONTRIBUTIONS TO PROJECT

- **Development of engine-based power plant** for heat and power generation.
- **Modernization of primary engine generator** for conversion of biofuels into energy.
- **Development of power plant** for heat and power generation
- **Manufacture of power plant** for heat and power generation.
- **Testing of engine-based power plant** for heat and power generation.
- **Feasibility study** and estimation of the market potential of the product.

## MAIN CONTACT

Dr. Khripach Nikolay
Tel: + 7 495 456 40 01
Fax: + 7 495 454 70 03
Email: khripachna@nami.ru

FSUE NAMI
125438
Avtomotornaya street, bld 2
Moscow
Russia

## EXPERIENCE AND FACILITIES

**The Institute FSUE 'NAMI' has all the necessary technical, technological and computer means to provide fundamental, theoretical and applied testing, construction, manufacture of automobile equipment, internal combustion engines, its units and assemblies, as well as traditional and alternative fuels and power generators.**

The concentration of research based capabilities and highly skilled specialists inside NAMI allows the Institute to be a leader in the field of oriented fundamental theoretical developments, innovative developments and certification of automobile equipment against Russian and international standards.

Based on its experience, NAMI meets objectives which guarantee successful project implementation:

- Theoretical and experimental research to create high efficiency and low toxicity working processes of automobile engines with internal and external mixing;
- Development of an improved scientific basis for vehicles and engines design;
- Theoretical and experimental research to create feeding systems for diesel engines to operate on alternative fuels;
- Analysis of the energetic and economic efficiency of alternative fuels;
- Creation of multi-purpose power plants, working on alternative fuels.

## ACHIEVEMENTS AND OUTCOMES

The project goal was development of compact autonomous systems for decentralized heat- and power supply for small-scale communal and social facilities, based on environmentally sound technologies for biomass conversion to biofuel.

In this project, a unit for heat and electric power generation has been developed. The fuel is a mixture of diesel and biofuels produced from biomass. The power plant includes production of synthesis gas and reduction of nitrogen oxides in the exhaust gases. The internal combustion engine has been adapted to run on biofuels, including replacing parts and sealing elements in the fuel system with corrosion-resistant materials and modified valve timing. Fuel heating is applied to enable operation at subzero temperatures. NAMI have worked with BIC to develop a system for removing NOx from exhaust gases.

Acceptance testing has proved that the power plant AVTAB-1 can provide:

- Capacity of 100 kWe at design conditions;
- Heating power of up to 150 kWth;
- Efficiency of energy transformation into electric power at the most energy efficient regime of 33.3%; and efficiency of energy transformation into heat at the most energy efficient regime of 47.1%;
- Overall efficiency at the most energy efficient regime of 75.6%;
- Reduction of nitrogen oxides in exhaust gases of the engine power plant by 80.0 to 82.3%

All of the above results have met or exceeded the technical requirements of the project.

# Partner – The Likhachev Plant (AMO ZIL)

## CONTRIBUTIONS TO PROJECT

- **Execution of patent searches.**
- **Testing of power plant units.**
- **Participation in assembly of power plant for heat and power generation.**
- **Participation in testing of engine-based power plant for heat and power generation.**

## EXPERIENCE AND FACILITIES

**AMO ZIL (trademark 'ZIL') is the oldest Russian automobile plant. Since its establishment in 1924, ZIL has produced a wide range of vehicles including trucks, buses, and high-class automobiles.**

Nowadays, the company is developing dynamically. ZIL produces a wide range of trucks, vans, buses and limousines based on the ZIL chassis. The company also manufactures specialized vehicles and equipment including; ambulance cars; fire trucks; emergency repair vehicles and cross-country 4x4 etc.

ZIL recognizes the importance of quality improvement and continuously implements new devices in its products. This has resulted in exponential growth over the last five years. Most vehicles have a complete range of modifications and options available to suit customers' needs.

The market for stationary diesel engines for power production is considered by ZIL to be a potentially huge, new market where their automobile engine expertise could be of high value. ZIL is looking forward to working with NAMI in developing new technologies and products.

## ACHIEVEMENTS AND OUTCOMES

Patent searches have helped to identify a development plan and prioritise basic trends in this area and define a direction for our own research.

Bench tests of a power installation based on a diesel engine YAMZ-238M including generation of synthesis-gas and selective reduction of nitrogen oxides, have allowed key parameters and characteristics to be estimated as required in the technical specifications.

## MAIN CONTACT

Silin Sergey
Tel: + 7 495 677-26-28
Email: silin@amo-zil.ru

The Likhachev Plant (AMO ZIL)
115280
Avtozavodskaya street, bld 23
Moscow
Russia