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# Bioenergy

## Develop and optimize processes for energy production from biomass

The great majority of rural people in the countries of the South lack access to energy. Biomass, though often abundant there, is used only to supply basic household energy. Today, economic development demands access to production-grade energy, which is essential to raw material processing and food preservation and, more generally, to the development of economic activities that will generate jobs and income.

| The main teams |
|---|
| **Trimatec Competitiveness cluster on green technologies** |
| **DERBI Competitiveness cluster - Development of Renewable Energy/ Building/Industry** |
| **BIOÉNERGIESUD Network** |
| **UR Biomass & Energy** (CIRAD) *12 scientists* |
| **Other teams working in this area** |
| **UMR IATE Agro-polymer Engineering and Emerging Technologies** (CIRAD/INRA/Montpellier SupAgro/UM2) *49 scientists* |
| **UR LBE Laboratory of Environmental Biotechnology** (INRA) *16 scientists* |

The objective of the research being done by the ***UR «Biomass & Energy»*** **(CIRAD)** is to develop and optimize processes for energy production from biomass and to analyse how such processes may be developed in the countries of the South. Target applications include the production of heat, electricity and motive power. The unit focuses in particular on thermochemical biomass conversion processes involving pyrolysis, gasification and combustion. The knowledge thus acquired also contributes to longer-term development of second generation biofuels produced by thermochemical means.

The focus of the research work is twofold:
❶ How biomass fuels react under pyrolysis, gasification and combustion, and how to design innovative conversion processes: the research focuses on the influence of biomass type on the reactions, the factors that control conversion, the quality of the products obtained and their optimum use, and, in general, the optimization of recovery processes. The unit relies on experimental devices ranging from laboratory scale to semi-industrial pilots. Models for the behaviour of biomass during the various transformation phases are also being developed.

❷ How energy biomass processes are to be implemented: the research concentrates on an evaluation of the environmental impacts of the processes, development scenarios at the local, national and regional levels, the definition of an *ex ante* and *ex post* methodology to assess the viability of systems for energy production from biomass, with an integrated approach to technical, economic and environmental factors.

The unit works in partnership with the International Institute of Water Engineering and Environment (Burkina Faso), with which a common platform for research into biomass energy has been developed, the Forest Products Laboratory (Brazil) with which research on energy recovery from forest and tree-farm waste is being conducted, and the *Centro Agronómico de Investigación y Enseanza* (Costa Rica), with which work is being done on energy biomass development scenarios and their impacts.

The unit's main scientific facilities include a 200 m² platform of semi-industrial pilots, a motor and burner test bench for biomass-derived fuels, and laboratories to analyse products and by-products of the conversion reaction. ■

▲ *Pilot reactor for continuous fixed-bed biomass pyrolysis and gasification, CIRAD.*

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## Biomass of the Champagne vineyards, a renewable energy source for bottle production

The BioViVe project (wine-growing biomass for glass melting) seeks to feed a glass furnace directly with syngas derived from the woody by-products of the pruning and grubbing-up of vines, to replace fossil fuels. This gas will be specifically tailored to the needs of glass melting and will be tested in Verallia's furnace in Oiry (Marne), so the project partners—Saint-Gobain Emballage, GDF SUEZ, XYLOWATT, CIRAD and the *Comité Interprofessionnel du Vin de Champagne*—will be doing laboratory research, semi-industrial combustion cell tests and long-term tests on the Oiry industrial furnace under normal production conditions. This project will also lead to the creation of an ongoing biomass collection industry in the Champagne vineyards.

The project's ultimate goal is to achieve about a 7% replacement of fossil fuels with biomass. In addition, the knowledge and experience gained thereby will enable partners to consider more significant development of the sector and a transition to a 50% replacement rate.

The UR "Biomass & Energy" is particularly involved in two project tasks, which it coordinates. The first is the characterization and mobilization of the waste vine-wood resource. The second concerns the project's research aimed at understanding and optimizing the staged gasification process, to achieve an increase in the heating value of the syngas. Gasification research is "Biomass and energy" research unit's core activity, to provide an effective biomass recovery solution to facilitate access to energy in the South.

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# Improving biofuel combustion for the rural South

One glass (20 cl)! That's how much diesel or biofuel, on average, a rural family in the South (Africa, Pacific, Amazon…) needs to have electricity for 4 to 8 hours a day. But the primary need is to have a little power, occasionally or intermittently, for energy services. In Africa, this takes the form of grain milling, water pumping and handicrafts using powered hand tools. Throughout the rural developing world, the requisite power is obtained from small gasoline—or most often diesel—engines. Lister type diesel engines have been widespread on all continents for decades.

In Africa, the development of multifunctional platforms (United Nations Development Programme/MFP) has encouraged their commercialization. These 5- to 15-hp engines are found under various names in the various countries and regions (Peter Lister, Rhino, Fieldmarshal, Imex, Elephant, Jumbo, Goldstar…). They are manufactured in India from a model that has long been obsolete in England. They are hardy, undemanding engines and, especially, cost much less than newer diesels of equivalent power. They are widespread among millers and for water pumping, and attempts to adapt them to use local biofuels were made in the early 80s.

But problems of combustion chamber fouling arose right from initial testing, discouraging any decision to use local pure vegetable oils in rural areas. CIRAD's objective is to provide an appropriate technology solution to allow the use of alternative fuels from local oilseeds. The study and recent development of a very inexpensive part—€50—that is easy to fabricate and install locally will enable hundreds of thousands of these engines to use biofuel in place of diesel. As of today palm, cottonseed or jatropha oil are the favoured types.

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▲ *An example of an 8-hp Lister Rhino diesel engine installed on a multifunctional platform, here coupled to a power generator and a husker. 2IE, Burkina Faso, 2011.*

# The DANAC project

## activated anaerobic digestion—biomimicry for anaerobic digestion

Today, industrial technologies are being used to produce the various biochemical processes of anaerobic digestion within a single reactor. Over this past decade, pre-processing or co-processing anaerobic digestion methods have appeared whose purpose was to make the matter to be digested more readily available. To date, however, none of these technologies has been able to exceed the threshold of 60% degradation of the organic matter, and so biogas production has been limited. It should be noted that anaerobic digestion is a very common process, especially in living beings' gastrointestinal tract. In these ecosystems, its may digest 61 to 76% of the organic matter.

These results suggest that the living world has developed systems that overcome the obstacle of organic matter availability and so optimize the transformation of matter into energetic compounds. The objective of the DANAC project is to thoroughly analyse living beings' digestion processes and, by mimicry, to develop new processes for producing biogas from waste, with a better than 70% rate of organic matter degradation. LBE is coordinating this project in partnership with the UR "Hydrosystems and Bioprocesses" (IRSTEA), the Paris Sud-Ouest proteomic analysis platform (INRA), the UMR "Biogeochemistry and Ecology of Continental Environments" (AgroParisTech, CNRS, ENS, IRD, *Universités Paris 6* and *Paris 12*) and Suez Environnement.

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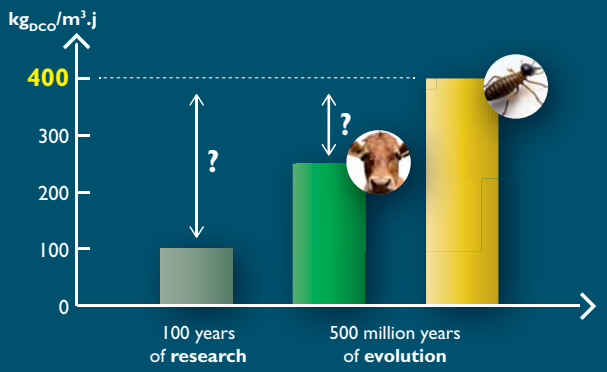


▲ *The DANAC project's objectives: through biomimicry, to seek novel technological solutions for the optimization of solid waste treatment.*

# SYMBIOSE project
## study and optimization of anaerobic bacteria/microalgae coupling for bioenergy production


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Many research and development programmes are looking into the use of microalgae for energy production or the capture of $CO_2$ of industrial origin. The SYMBIOSE project, coordinated by Naskeo (in collaboration with LBE [INRA] / UMR "Ecology of Coastal Marine Systems" [UM2-IRD-CNRS-UM1-French Research Institute for Exploitation of the Sea (IFREMER)] / "Biological Control of Artificial Ecosystems" team [National Institute for Research in Computer Science and Control] / Laboratory of Physiology and Biotechnology of Algae [IFREMER]) seeks to explore a parallel and often complementary approach to the conventional energy production technologies using these microorganisms: coupling microalgae cultures that capture industrial $CO_2$ through an anaerobic digestion process in order to recycle crop nutrients and produce methane. The project builds on recent advances in the control of microalgae cultures and anaerobic digestion processes by including lagoon ecosystem ecology and an eco-design approach, and aims to explore new avenues of research:

- identification and characterization of photosynthetic ecosystems capable of withstanding extreme growing conditions;
- use of anaerobic co-digestion in a two-step process in order to control the flow of nutrients;
- modelling and control of two biological systems;
- integration into a single process through an eco-design approach.

This project aims to exploit mechanisms that occur in natural aquatic environments while controlling them to optimize light and $CO_2$ capture efficiency and crop sustainability. Most projects concerned with mass microalgae production will benefit from these advances. Expected benefits from these results:

- less use of external nitrogen and phosphorus on photosynthetic biomass crops;
- simultaneous purification of gaseous effluents and organic waste;
- lower costs and increased energy efficiency;
- improved system resilience;
- prospect of a new model for sustainable energy production.

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▲ *The Algotron, a fully instrumented pilot project of the SYMBIOSE project, combining cultivation of microalgae and anaerobic digestion, on the LBE (INRA) site.*

# PEACE project
## production of Energy from Agro-resources by Energy-efficient Conversion

Lignocellulosic biomass must be pre-processed to achieve efficient enzymatic hydrolysis of cell wall polysaccharides, a key step in the production of ethanol and methane. Four research units (UMR IATE, UR LBE, UR Biomass & Energy, UMR *Institut Jean-Pierre Bourgin*) came together to form the 3BCAR Carnot Institute* in order to study and develop an original method for straw pre-processing that would be energy-efficient and have a positive mass/energy balance after ethanol fermentation and methanogenesis.

As a first step, the biomass is subjected to moderate heat treatment, which degrades its mechanical properties. To optimize this treatment, it is combined with chemical impregnation to allow embrittlement and structural modification of the cell wall architecture to destructure the core material and increase its reactivity. The heated material is then finely triturated in high-speed mills designed to produce powders with a particle size of less than 50 µm. The powders obtained undergo enzymatic post-processing to open up those parts of the cell wall that resisted the first pre-processing steps, and are then used as substrates for ethanol fermentation and methanation tests. The samples are analysed at all stages to provide clues to the relationship between their composition, properties and behaviour under the processing employed. Processes are observed in detail to establish energy balances. The overall result will be compared with existing methods.

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* Bioenergy, Biomolecules and Biomaterials from Renewable Carbon: www.3bcar.fr