



Road Map for Second-Generation Biofuels



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Road Map for Second-Generation Biofuels

Priority research demonstrators for new energy technologies have been identified in the French national energy research strategy and in the work of the operational committee for research under the “Grenelle de l’Environnement” summit.

The present document outlines the main stages of a road map, specifying the needs for demonstrator projects pertaining to second generation biofuels, and sets the priorities that will be addressed by the demonstrator fund.

> Background and stakes

France, like the rest of the world, faces the twin challenges of climate change and excessive dependence on fossil fuels. Confronted with the necessity of reducing greenhouse gas emissions while also diversifying energy sources, biomass is a renewable energy resource that is particularly suitable for the production of liquid fuels on which the vast majority of passenger and goods transport vehicles are dependent, on land, on sea and in the air. Transport is responsible for close to one quarter of greenhouse gas emissions in France and in Europe. From 1990 to 2007 the transport sector registered the largest increase in GHG emissions. It is therefore vital to find ways to reduce these emissions. First- and second-generation biofuels constitute a way to simultaneously reduce the sector’s dependence on petroleum products and to reduce GHG emissions in the short and medium term, provided that these biofuels are sustainably produced.

European directive 2003/30/EC sets the target of 5.75% biofuels in the motor fuels market by 2010 for European Union countries. The French transposition of this European directive, introduced by Prime Minister Jean-Pierre Raffarin and accelerated a few months later by PM Dominique de Villepin, sets target levels at 5.75% in 2008, 7% in 2010 and 10% in 2015, placing France among the leaders in Europe for biofuel use. At present all biofuels are produced using so-called first-generation processes that exploit only plant storage organs. These processes limit the range of resources that can be exploited for biofuels, interfere with certain food supply chains, and have energy and environmental balances that could be considerably improved. These supply chains also produce protein coproducts used for animal feed. With second-generation processes this feed would have to be obtained elsewhere, taking up other agricultural land.

Accordingly research and development work has been started to pave the way for a progressive and sensible transition to so-called second-generation processes that use whole-plant resources to produce biofuels, thus ensuring greater complementarity rather than competition between the different uses of biomass, in particular in relation to the food supply chain, while reducing pressure on the environment.

This new generation of biofuels, requiring sophisticated transformation technologies to convert a wider range of biomass resources (agriculture and forestry resources, dedicated crops, waste, etc.), aims to significantly reduce greenhouse gas emissions and the cost of producing biofuels.

The technical, economic and environmental aspects of these new biomass conversion processes that use primarily lignocellulosic resources must be optimised and validated in demonstration installations prior to industrial deployment. In addition the conditions in which biomass feedstock resources are selected, harvested, stored and prepared must be evaluated and simulated, the biomass yield being one of the key factors to expected output.

The production conditions and processes for biofuels in the medium and long term, in France and elsewhere, must be anticipated today.

> Potential technologies

Technologies that have potential for second-generation biofuel production are of two sorts:

- Thermochemical technologies, relying mainly on pyrolysis-gasification of biomass
- Biological technologies, involving enzymatic hydrolysis and fermentation of biomass.

Thermochemical conversion

The first stage of the process, called the pyrolysis-gasification stage, can be used with a number of carbon feedstocks. This process is currently used industrially by SASOL in South Africa to transform coal (coal to liquid, CTL). Feasibility studies are underway in the United States, India and most importantly China, with the aim of applying this technology to coal conversion. Plants to convert natural gas to liquids are projected in Australia, Qatar and Nigeria (gas to liquid, GTL).

Whether by a hydrothermal pathway or a dry process, the synthesis gas obtained by gasification (CO/H₂, a mixture of carbon monoxide and hydrogen) is then purified and transformed.

1°) Using the Fischer-Tropsch method the gas is condensed into a wax that is a feedstock for the synthesis of diesel and kerosene fuels (biomass to liquid, BTL).

2°) By methanation the gas is converted to synthetic natural gas (SNG). This second pathway would appear to be a less demanding alternative. This gaseous fuel could be distributed directly under pressure via existing natural gas infrastructure (even to individual retail customers) or routed to other applications.

Application of these processes to biomass is still in development phases. The difficulties encountered with this technology are the following:

- Harvesting and preparation of biomass, by nature widely dispersed and with a moderate energy content, necessitating preconditioning stages (such as oven drying, pyrolysis, hydrothermal conversion to bio oils, etc.)
- Gasification and gas purification (tars, alkalis, dust particles, etc.)
- Carbon yield as well as the energy efficiency of the process.

In parallel, coprocessing of all or part of the biomass resource mixed with other carbon feedstocks (charcoal, petroleum residues, organic waste, etc.) may offer an intermediate solution with respect to resource availability.

To bring down the investment required to implement these technologies, each gasification/synthesis installation must process in excess of one million tonnes of biomass yearly. This volume requirement implies pretreatment units able of processing hundreds of thousands of tonnes of biomass a year, to obtain an easily transported feedstock with high energy content.

Biochemical conversion

The fuels considered here as second-generation fuels are bioethanol and other energy vectors obtained by fermentation of lignocellulosic feedstocks.

This conversion pathway for lignocellulosic biomass transforms cellulose and hemicellulose, two of the three main polymers that make up plant matter, by biological processes, to obtain fuels (ethanol, butanol, fatty acids, etc.). The third component, lignin, is used primarily to meet the energy needs of the conversion process, and/or is sold as a feedstock for chemicals and materials industries.

The main goals to be attained concerning this pathway are:

- Demonstrate technical feasibility
- Prove economic profitability in the medium term (2012-2015)
- Establish sustainability, while diversifying sources of raw materials and distinguishing the process technologically from other projects around the world.

Pretreatment and hydrolysis of lignocellulose are technical and economic bottlenecks that must be eliminated, in order to obtain fermentable sugars for later stages at a competitive cost.

The successful industrial development of the biological pathway for production of biofuels from lignocellulosic biomass necessitates a systems approach integrating the different processes in the biomass value chain, making the fullest possible use of the plant matter, with technical, economic and environmental validation of the various technological building blocks.

Road Map for Second-Generation Biofuels

Under the auspices of the Champagne-Ardenne competitive cluster, the Crédit Agricole bank has brought together Champagne Céréales (an agricultural cooperative), the oil company Total, sugar producer Tereos and the Office National des Forêts along with public and private research laboratories (IFP, INRA, ARD, Lesaffre) to back the FUTUROL demonstration project. The laboratory partners have demonstrated, at the lab scale and in small pilot installations, their ability to extract sugars from lignocellulosic plant matter, and their mastery of molecular biology technologies that enable the creation of new enzymes that can complete and improve current industrially manufactured preparations.

The biochemical conversion demonstrator selected in early 2008 has a total budget of €2 million, 40% of which comes from public funds (Oséo Innovation). It includes:

- Full-plant biomass pretreatment unit (straw and wood)
- Enzymatic hydrolysis unit to obtain fermentable sugars
- Fermentation unit to produce enzymes
- Sugar fermentation unit to produce ethanol.

This technological facility is integrated into a well structured research-development programme with the objective of developing within 10 years a value chain in France based on second-generation enzyme technology. The experimental programme covers resource issues (cultivation systems, improvement of varieties, environmental balance sheets etc.), pretreatment (crushing and milling, catalysts, separation), hydrolysis (process optimisation, selection of enzyme strains), fermentation (pentoses, minimisation of inhibitors, valuable uses for CO₂), management of coproducts and limitation of consumption and discharges.

The vocation of this consortium is to develop a set of technologies that will then be licensed in France and abroad.

> Research road map

Since 2005 France has coordinated research under the Programme National de Recherche sur les Bioénergies (PNRB) funded by the Agence Nationale de la Recherche (ANR) and implemented by ADEME. A total of 32 projects have been supported with funding of €3 million, out of a total budget of €7 million. The ANR Bioenergies programme launched in 2008 ensures continuation of the activities started under PNRB.

The research road map for the demonstrator fund pursues four objectives:

- Develop high-yielding and economically viable technologies, to maximise available biomass per hectare and to diversify exploitable bioresources, so as to avoid competition with other present and future uses of biomass (foodstuffs, materials, heat/ electricity, chemicals).
- A representative range of pilot projects will provide information to evaluate mass and energy balances, the environmental and social impacts of the pathways under consideration, due not only to production techniques for second-generation biofuels, but also to cultivation and processing of the biomass resources.
- Development of the biorefinery concept integrating physical, biological and chemical processes, in order to obtain the most value from all the feedstock components. Biofuel production is one of the market outlets, along with other valuable products (synthetic molecules, for instance) that will form the basis for plant-based organic chemicals, replacing petrochemicals.
- Development of thermochemical and biological production chains for new energy vectors, and for lipids obtained from algae and micro-organisms.

> Research demonstrator needs

Research work has already been accomplished that significantly advances the understanding of thermochemical conversion of biomass (for instance, reducing the oxidising behaviour of synthesis gases) and biological steps (raising the output of enzymatic hydrolysis) for producing biofuels.

It is now time to deploy research demonstrators of significant size in France, in order to evaluate and validate the industrial, economic, social and environmental potential of the technologies now being developed for different pathways, with a view to producing second-generation biofuels.

With the FUTOROL project funded by OSEO Innovation, France has acquired a platform that brings together the full range of public and private-sector actors in an integrated research and demonstration project dedicated to biological conversion. FUTOROL plans to construct a pilot plant designed to process 1 tonne dry matter per day, and then a prototype with a capacity of 10 to 20 tonnes/day.

A research demonstrator for thermochemical conversion has not yet been planned in France, in contrast with Germany for instance, where research on thermochemical conversion of biomass (BTL) is well advanced (see the international panorama in annex B):

- The Choren corporation, in collaboration with Shell, has developed a staged gasification process using biomass. This company inaugurated its first industrial pilot plant using an autothermal process in April 2008, and has announced that it is working on a 200 000 t/yr industrial project in Germany for Shell.
- The University of Freiberg and the Institute for Energy and Chemical Process Engineering are working with partners Total, Volkswagen and Choren on a small pilot plant in the framework of the European RENEW project.
- The FZK research centre (Karlsruhe) has perfected a promising rapid pyrolysis technique and has built a pilot unit for research.

France also possesses strong points in several domains:

- Fischer-Tropsch synthesis process developed by the Institut Français du Pétrole (IFP) and marketed by its subsidiary Axens.
- With the acquisition of Lurgi, Air Liquide has gained access to several gasification and purification technologies applicable to synthesis gases.
- The TENERDIS (Rhône-Alpes) and IAR (Picardie-Champagne-Ardenne) competitive clusters have assembled teams devoted to biomass drying, pyrolysis and gasification, with members from a number of publicly-funded institutions in France. These projects are in large part funded by ANR, under the PNRB national energy research programme, and since 2008 the Bioenergies programme. They are managed by ADEME.
- The Commissariat à l'Énergie Atomique (CEA) has been pursuing scientific and technological research on an allothermal process for several years, also with support from PNRB. If successful this work will make it possible to extract more from biomass, on the condition that an economical exogenous high-temperature energy source with low CO₂ emissions is available, along with hydrogen. Energy input in the form of nuclear power (or even heat from a high-temperature nuclear reactor) and hydrogen added by electrolysis or thermal splitting of water are two hypothetical possibilities that justify embarking on this programme even though its feasibility and industrial deployment are far down the line. CEA and its partners have programmed a pre-industrial operation based on existing technological building blocks, in the framework of measures to spur economic development in the Meuse and Haute Marne départements.
- A number of organisations and companies (SOFIPROTEOL, GDF, among others) are working to build industrial value chains for second-generation biofuels using thermochemical conversion, in particular with the partners mentioned above (Air Liquide, TENERDIS, CEA, IFP, etc.).

> Research–demonstration–deployment timetable

Period	Objectives
2009 – 2011	The major production options for second-generation biofuels, thermochemical and biological conversion, are the focus of research demonstrators and development platforms. Logistics (biomass preparation, transport, pretreatment) are studied and tested, supported by research programmes. Research continues on microbial pathways to produce hydrogen and lipids.
2012 – 2015	A technological portfolio for second-generation biofuels is validated. The first industrial-scale operations can be launched, on the basis of results obtained through research demonstrators. Aiming to maintain the dynamics of progress, research programmes are pursued to follow through on improving and adapting industrial processes, and integrating them into biomass value chains. In particular, acquisition of breakthrough technologies to shift from autothermal to allothermal units is tested at a pre-industrial scale. Development of research demonstrators focusing on microbial pathways to obtain lipids, hydrogen and other energy vectors is initiated.
2015 – 2020	All the elements required for production of biofuels (technology, resources, controlled environmental impact) are acquired. Industrial installations are in operation and supply a growing share of the market. Second-generation biofuel production installations are effectively integrated into biorefineries.

ANNEX A

Sources:

- Stratégie nationale sur la recherche dans le domaine de l'énergie (Ministry for the Economy, Finance and Industrie, DGEMP, France, 2007 <http://www.industrie.gouv.fr/energie/recherche/presentation-snre.htm>)
- Jarry Committee Report to the Prime Minister
- European Biofuels Technology Platform (<http://www.biofuelstp.eu/>)
- ANR, PNRB reference documents
- ADEME in-house documents

ANNEX B

A selective panorama of second-generation biofuel production demonstrators in operation or under construction

Thermochemical Conversion

GERMANY

BTL research highly advanced

The Lurgi firm, recently integrated into Groupe Air Liquide, possesses rapid pyrolysis, gasification and gas purification technologies.

Choren, a subsidiary of Shell, is also developing biomass gasification technology. This company inaugurated its first industrial pilot plant using

an autothermal process on 17 April 2008, and has announced that it is working on a 200 000 t/yr industrial project in Germany for Shell.

The University of Freiberg and the Institute for Energy and Chemical Process Engineering are working with partners Total, Volkswagen on a small pilot plant in the framework of the European RENEW project.

CUTEC's ARTFUEL process is the fruit of cooperation between three Länder and Volkswagen in Brandenburg. It comprises 0.4 MWth circulating fluidised-bed reactor, gas purification and Fischer-Tropsch synthesis. The FZK research centre (Karlsruhe) has perfected a promising rapid pyrolysis technique and has built a pilot unit for research.

SWEDEN

Chemrec has implemented a black liquor gasifier, and aims to achieve synthesis of biofuels (Fischer-Tropsch) with demonstration plants in Pitea, Sweden. Sweden is also participating in the European CHRISGAS project, with an 18 MW unit. Conversion of biomass to synthetic natural gas to supply a pipeline is under study. A 100 MW gasifier is to be installed in Göteborg.

FINLAND

VTT is developing first a 500 kW gasification unit (2008-2010), and then aims to build a 150-400 MW unit integrated into a paper-making plant, to produce biodiesel fuel from biomass. The first commercial plant (Fischer-Tropsch) is planned for 2012-2014.

UNITED STATES

The Department of Energy granted \$7.7 million in late 2007 to four gasification demonstration projects for second-generation biofuel production.

Biological Conversion

DENMARK

The MAXIFUEL project pursued by the BioGasol company is the product of work at the Denmark Technological University (DTU). The present pilot unit at DTU has a capacity of 1 tonne/hour. BioGasol recently announced that it is building a demonstration plant on the island of Bornholm, to start operation in 2009. The MAXIFUEL process uses a specifically adapted thermophilic strain of bacteria to convert pentoses obtained by fermentation of ethanol. The residues of the process are recovered as biogas and used to supply energy to the plant, making it self-sufficient. In parallel BioGasol receives \$24.3 million in funding from the United States Department of Energy, under a collaborative project with the Pacific Ethanol company. This project is devoted to integrating the BioGasol technology in an existing 10-million-litre/year Pacific Ethanol demonstration plant in Boardman, Oregon. A second Danish project is IBUS, involving partners Inbicon and Dong Energy. The consortium has received 7.5 million to build a demonstrator in Kalundborg.

SWEDEN

A 400 litre/day pilot ethanol unit funded by the Swedish energy agency is located in Örnköldsvik. Some of the testing conducted under the European NILE project (FP6) coordinated by IFP is carried out at this installation.

SPAIN

Abengoa is currently building a 70 tonne/day commercial demonstration plant in Salamanca

with European funding. Abengoa also has another project underway in the United States with funding from US DOE.

CANADA

In late 2007 the Canadian Environment Ministry opened the NextGen Biofuels Fund™ fund to provide CA\$500 million in repayable advances for the construction of cellulosic ethanol plants. Iogen has recently filed a project.

JAPAN

Bioethanol Japan Kansai is opening a production facility in Sakai near Osaka with an initial capacity of 1 000 t/year.

UNITED STATES

Recent DOE financing for pilot and demonstration plants:

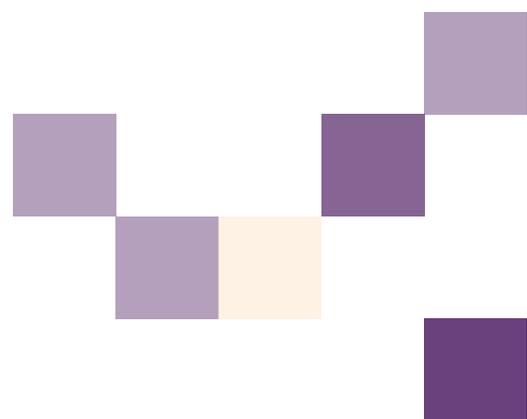
- 6 pre-industrial projects (scale 1) with \$385 million in DOE funding, and total investment valued at about \$1.2 billion. Participants announced in February 2007 : Abengoa, Alico, Iogen, BlueFire, Brion et RangeFuels.
- \$114 million over four years allocated to four pilot-scale projects (1/10) in January 2008. Lignol, ICM, Pacific Ethanol with the BioGasol process; the fourth project is a thermochemical conversion unit.
- DOE announced in April 2008 that it would provide \$86 million over four years for the construction of three other cellulosic ethanol refineries, by Ecofin LLC, Mascoma, and RSE Pulp & Chemical LLC.

The firm Coskata in association with GM announced in late April 2008 that it would build a demonstration unit for its "hybrid" process to produce ethanol by fermentation of syngas obtained by thermochemical methods. Other actors: Chevron and Weyerhaeuser, Shell and Codexis, Shell and Virent Energy Systems, BP and DuPont.

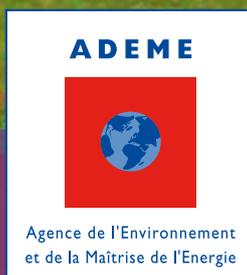


ADEME in brief

The French Agency for Environment and Energy Management (ADEME) is a public agency under the joint authority of the French Ministry for Ecology, Energy, Sustainable Development, and the Ministry of Higher Education and Research. The agency is active in the implementation of public policy in the areas of the environment, energy and sustainable development. ADEME provides expertise and advisory services to companies, local authorities, government bodies and the public at large, helping these actors finance projects, in particular research, in five areas (waste management, soil conservation, energy efficiency and renewable energy, air quality and noise abatement) and assists them in their progress towards sustainable development.



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