



RENEWABLE ENERGY RESEARCH

Primary energy sources are divided into depletable sources (fossil fuels, nuclear fuels) and nondepletable sources (including wind, solar, geothermal, tidal, hydroelectric, bioenergy). Today, most of the world's primary energy still comes from the burning of carbon-based fossil fuels, so research aimed at harnessing renewable sources of energy is critical in order to respond to the world's energy challenges.

Within the context of the United Nations Framework Agreement on Climate Change, the 2015 Paris agreement on climate change, to reduce greenhouse gas emission, was signed by 195 countries, attesting to the world's awareness of the need to shift to nonpolluting and renewable sources of energy. The share of renewable energies have raised to 18% of the total world energy consumption.



BIOMASS, FRANCE'S LEADING SOURCE OF RENEWABLE ENERGY

In France, the use of renewable energy has long been concentrated on the production of electricity through a growing number of wind engines and solar panels, and on cogeneration, a process of simultaneous production of electricity and heat from petroleum products, natural gas, waste products, coal, and biomass.

The two main sources of renewable energy in France and the European Union are biomass and, to a lesser extent, hydropower. Biomass—the biodegradable portion of products, wastes, and residues from agriculture, forestry, industry, and household consumption—is the

“Hydroelectric power has been in use in France since the 1920”

leading source of renewable energy consumed in France (52% of renewable consumption, second in Europe after Germany), ahead of hydropower, wind energy, and solar energy. Boilers are supplied with wood byproducts and with wastes from the production of paper and biofuels.

Hydroelectric power has been in use in France on an industrial scale since the 1920s. Since then France has achieved near-total independence in the generation of electricity through hydropower and, later, through nuclear energy. By contrast, France remains heavily dependent on fossil fuel imports for heating and transportation.

INVESTMENT IN CARBON-FREE TECHNOLOGIES

In 2016, renewable energy accounted for 16% of France's total energy production.

In the same year, EDF Énergies Nouvelles and First Solar came together to create a solar energy business by, among other things, building France's largest plant for the manufacture of solar panels using thin-film photovoltaic technology. Through these and other initiatives France aspires to become a leader in carbon-free technologies such as solar energy.

Among the objectives of the national energy policy is to raise to 32% the share of the nation's electrical consumption coming from wind, biomass, and hydropower by 2030.

STRATEGY FOR LOW-CARBON ENERGY AND SUSTAINABLE DEVELOPMENT

> Respect for the environment

Energy consumption in buildings—for heat, hot water, and cooking— is currently heavily dependent on fossil fuels. As part of the environmental movement for design and construction of so-called HEQ buildings (HEQ stands for High Environmental Quality), the concept of the “positive energy building” along with better insulation, is a critical challenge

> The fight against climate change

Technological research is helping us fight climate change through projects designed to capture and sequester carbon (for example, underground), enabling reductions in greenhouse gas emissions from the generation of electricity, especially in countries that still make heavy use of coal.

> Biofuels

The large-scale application of ethanol is constrained by the resources required to extract oils from the seeds of plants such as sunflower, canola (rapeseed), and soy so that the oils can be used as biofuels in eco-friendly automobiles fitted with specially adapted engines. Mixed with conventional fuel, they can also be used in diesel engines. Esterification, using ethanol or methanol, produces a biofuel such as methyl ester of canola, which already can be combined with gasoline at a strength of 5% or even 30% for specially equipped fleets. The environmental impact of such fuels comes into play when increased production of crops destined for the production of fuel crowds out other crops.

Research is also playing an important role in the emergence of new technologies that facilitate the use of second-generation biofuels through a process of biomass gasification. The mixture that results from the process is put through a catalyzer to produce synthetic hydrocarbons, prefiguring the appearance of third-generation agrifuels based on micro-algae.

> Nuclear energy: yes, but...

The improvement of the image of nuclear energy in public opinion has come about through advances in the processing of nuclear wastes. Research efforts are focused on packaging wastes and on their safe storage deep underground, complementing other research on so-called fourth-generation reactors. Advances have already been made, for example, in reducing the volume required for radioactive wastes (since 1991 the volume of mid- to high-activity waste with a long half-life has been reduced by a factor of six) and in confinement technologies.

> Better storage

New research work is under way on new high-performance energy solutions in several fields. Technologies that are still uncompetitive—such as solar energy, both photovoltaic and thermal (micro-generation, heat pumps)—will become more viable. Sea-based technologies, such as tidal and wave-based generation, are also the subject of extensive experimentation. Wind energy, fuel cells, and carbon gas storage provide further focal points for research and development. Work is also under way on batteries capable of storing far greater amounts of electricity than at present.



ENERGY EFFICIENCY, A MAJOR RESEARCH FOCUS

Renewable energies, already a major research focus in France, include bioenergy, geothermal energy, thermodynamic heating, solar energy (thermal, photovoltaic, concentration), wind energy, hydroelectric and marine energy, and hydrogen-based generation. The goal is to ensure greater energy efficiency from all technologies and to develop alternatives to technologies based on fossil fuels.

Renewable energies are analyzed for their output and emission levels. Wind and solar energy are variable in their output; biomass produces emissions but is more climate friendly than fossil fuels. Therefore the national energy research strategy emphasizes energy efficiency, solar energy, energy storage, biofuels, and sea-based energies.

RESEARCH DIRECTIONS AND RESEARCH FUNDING

■ ADEME, Agence de l'environnement et de la maîtrise de l'énergie

(Agency on the environment and energy management),
www.ademe.fr/recherche

ADEME is developing a new system to support research, development, and innovation in the fields of energy, air and soil quality, and the management of wastes and noise. The new system will provide support through the end of 2013. ADEME is also responsible for coordinating and guiding research and development in its areas of activity. Publicly funded research is conducted in France's universities and other academic institutions, public scientific and technological bodies, public industrial and commercial organizations, and public-interest foundations and associations. Both public and private research bodies can qualify for funding from ADEME.

ADEME has established 10 major research programs in the fields of energy and the environment, around two priority themes:

Ecologically responsible production and consumption

The purpose of these programs is to develop organizational and technological responses to reduce the environmental and energy impact of human activities

- > Bioenergy and bioproducts
- > Capture and storage of CO₂
- > Eco-technologies and processes for better air and soil quality and cleaner waste management
- > Impacts of atmospheric pollution and noise; metrology
- > Generation of electricity from renewable resources
- > Smart grids and energy storage

Sustainable cities and regions

These programs are designed to increase our knowledge of the effects of human activity on the environment and on human health and behavior.

- > Green buildings
- > Impacts of soil pollution, environmental assessment of wastes, and sustainable soil management practices
- > Socioeconomic forecasting
- > Clean and green transportation

In these major research areas, ADEME is developing forecasting exercises in cooperation with experts from public-sector research bodies and private enterprise:

- > Second-generation biofuel
- > Positive-energy and low-carbon buildings and developments
- > CO₂ capture and underground sequestering
- > Private motor vehicles and fuels in 2050
- > Renewable marine energy
- > Intelligent electrical networks and systems for the integration of renewable energies



■ ANCRE, Alliance nationale de coordination de la recherche pour l'énergie

(the national alliance for the coordination of energy research), www.allianceenergie.fr

Consistent with the national energy strategy and the strategic directions laid out by ADEME, ANCRE maintains a coordinated policy of projects in research and innovation (R&I). In addition to its three founding members—the CEA (Commissariat à l'Énergie Atomique et aux Énergies Alternatives, French commission on atomic energy and alternative energy), the CNRS (the French national center for scientific research), and IFP Énergies Nouvelles—ANCRE also counts among its membership all French public research bodies involved in energy issues. To ensure the industrial applicability of its work, ANCRE also involves energy firms in its planning and programs.

■ ANR, Agence nationale de la recherche

(national research agency), www.agence-nationale-recherche.fr

As a mechanism for financing research-support projects, the ANR focuses simultaneously on new energy technologies (photovoltaic, bioenergy, hydrogen and fuel cells, energy storage, CO₂ capture and sequestration) and energy efficiency in construction, manufacturing, and transportation. The ANR finances about 70 research projects in its annual programming.

More than 85% of the projects financed are public-private partnerships, with the ANR's share amounting to about €65 million. Since its creation in 2005, the ANR has committed more than €320 million to finance more than 400 projects.

■ Institut Carnot www.instituts-carnot.eu

The network of the 33 Carnot Institutes is dedicated to developing research partnerships with socioeconomic actors (large industrial groups, small and mid-sized businesses, startups, and local governments) and to promoting transfers of technology. In order to respond to major economic and social challenges, including renewable energy, the Carnot Institutes welcome doctoral candidates into their research laboratories to spread competence in the fields of energy and the environment.



MAJOR RESEARCH ORGANIZATIONS

■ CEA, Commissariat à l'énergie atomique et aux énergies alternatives (French commission on atomic and alternative energy)

Based in 10 facilities throughout France, the CEA is active in four fields: low-carbon energy, defense and security, information technologies, and health technologies:

www.cea.fr

■ CIRAD, agricultural research for development

« Biomass energy and the societies of the global South » is a research program dedicated to emerging energy issues and the terms under which bioenergy can be used for the benefit of the people of the global South: www.cirad.fr



■ ÉNERGIES Rhône-Alpes and the universities of Grenoble

This research cluster is devoted to « renewable energy and the technical, economic, and social aspects of energy efficiency » It provides a structure for energy-related research in the region. <http://ksup-gu.grenet.fr/clusters/energies/>

Doctoral departments of the Université Joseph Fourier and Grenoble INP:

- > Engineering for health, cognition, and the environment (ED 216): www.sante.ujf-grenoble.fr/edisce/
- > Energy mechanics (ED 219): <http://edimep2.grenoble-inp.fr>

■ EMMA, energy, mechanics, and materials

The scientific domains covered by EMMA at the Université Poincaré Nancy are mechanics, energy, matter and materials, processes for transforming materials and manufacturing components, and mechanical and energy systems.

- > Doctoral department on energy, mechanics, and materials (ED409): www.emma.uhp-nancy.fr

■ EULANEST

A project financed by France to increase the contribution of renewable and sustainable energy to meet the challenges of climate change (2009):

www.s2lat.eu/eulanest/Members/p1villar/eulanest-jointcall-2009

■ IBEB, Institut de biologie environnementale et biotechnologie (institute of environmental biology and biotechnology)

www-dsv.cea.fr

■ IFB, Institut Français de la Biodiversité (French institute of biodiversity)

Coordinates, leads, and disseminates research on biodiversity in response to the demands of researchers, habitat managers, and society: www.biodiversite-sbstta.org

■ IFP, Énergies nouvelles

A public organization for research, industrial innovation, and training, IFP Énergies Nouvelles is dedicated to developing highperformance, economical, clean, and sustainable technologies in the fields of energy, transportation, and the environment.

Since its creation it has obtained 40,000 patents in France and around the world, more than 13,500 of which are still in force.

An integral part of IFP Énergies Nouvelles, IFP School responds to the needs of industry by offering specialized training to junior engineers. Every year, it trains more than 600 students from around the world.

The institution has five key research objectives:

- > Capturing and sequestering CO₂ to combat greenhouse effects
- > Diversifying fuel sources
- > Developing clean, fuel-efficient vehicles
- > Getting the most out of raw materials used for energy and transportation
- > Extending the limits of possibility in oil and gas exploration and production

www.ifpenergiesnouvelles.fr





■ INES, Institut National de l'Énergie Solaire (national institute of solar energy)

INES engages in research to improve thermal and photovoltaic solar technologies for use in housing and other building construction: www.ines-solaire.com

■ Institut Carnot Énergies du futur

This research cluster is dedicated to renewable energy and the technical, economic, and social aspects of energy efficiency.

It carries out research in the Rhône-Alpes region on energy related materials, energy and buildings, energy management, storage, and renewable sources of energy:

www.energiesdufutur.fr

■ PROMES, Laboratoire des Procédés Matériaux et Énergie Solaire (laboratory for processes, materials, and solar energy)

PROMES is affiliated with the doctoral department on energy and the environment (ED 305), which provides research training in five broad scientific fields, including solar energy. PROMES is housed within the institute for research on life sciences and technologies (IRTSV) at the Université de Perpignan.

www.univ-perp.fr/fr/recherche/ecoles_doctorales.html

Equipped with high-performance solar ovens and concentrators, PROMES pursues the following objectives:

> Studying the conversion of solar energy into heat, cold, electricity, and hydrogen (energy vectors), particularly through thermal and thermo-chemical processes

> Developing eco-friendly processes and long-lasting materials

www.promes.cnrs.fr

■ Savoie Technolac Pôle

The center of excellence in solar and renewable energy at the Université de Savoie has conducted research on solar energy and eco-industries for two decades: www.savoie-technolac.com

The doctoral department on the sciences and engineering of systems, the environment, and organizations (SISEO; ED 489) specializes in energy and the environment, including eco-design and the treatment of gas-liquid effluents and wastes:

www.univ-savoie.fr/index.php?id=180

USEFUL LINKS

- **ADEME, Agence de l'Environnement et de la Maîtrise de l'Énergie** (French national agency on the environment and energy management): www.ademe.fr
- **ANCRE, Alliance Nationale de Coordination de la Recherche pour l'Énergie** (national alliance for the coordination of energy research): www.allianceenergie.fr
- **ANR, Agence Nationale de la Recherche** (national research agency): www.agence-nationale-recherche.fr
- **CITEPA, Centre Interprofessionnel Technique d'Études Atmosphériques** (interprofessional technical center for atmospheric research): www.citepa.org
- **CLER, Comité de Liaison des Énergies Renouvelables** (liaison committee for renewable energy): www.cler.org
- **Ecosources.info**, an information portal dedicated to renewable energy: www.ecosources.info/
- **EDF Énergies nouvelles**: www.edf-energies-nouvelles.com
- **Enercoop**, a cooperative for the supply of green energy: www.enercoop.fr
- **GERES, Groupe Énergies Renouvelables, Environnement et Solidarités** (renewable energy, environment, and mutual assistance group): www.geres.eu
- **Grenelle Environnement**: www.legrenelle-environnement.fr
- **INERIS, Institut National de l'Environnement Industriel et des Risques** (national institute on the industrial environment and risk): www.ineris.fr
- **IRD, Institut de Recherche pour le Développement** (institute for development research): www.ird.fr
- **Ministry of ecological and solidarity transition**: <https://www.ecologique-solidaire.gouv.fr/>
- **Planète énergies**, an online encyclopedia: www.planete-energies.com
- **Pôle d'Excellence Rurale Énergies Nouvelles (PEREN)** (cluster of excellence on new forms of rural energy): www.peren.org
- **SER, Syndicat des Énergies Renouvelables** (SER, renewable energy syndicate): www.enr.fr

GENERAL INFORMATION

- **Agence CampusFrance**: www.campusfrance.org
 - Catalog of doctoral departments and programs: www.campusfrance.org >Find your program>Level Doctoral
 - CampusBourse, a directory of grants and scholarships: www.campusfrance.org >Finance your program
- **ABG** promoting career opportunities for young PhDs: www.abg.fr
- **AERES**, the agency for the evaluation of research and higher education: www.aeres-evaluation.fr
- **ANDÈS**, National association for Science PhD: www.andes.asso.fr
- **ANR** - National agency for research: www.agence-nationale-recherche.fr
- **CNRS**, the national center for scientific research: www.cnrs.fr
 - CNRS directory of higher education and research: www.urec.cnrs.fr/annuaire/
 - CNRS quarterly magazine (in English): <http://www2.cnrs.fr/en/2.htm>
- **EURAXES**, mobility for researchers in Europe: http://ec.europa.eu/euraxess/index_en.cfm
- **Fondation Alfred Kastler** hospitality and support for foreign researchers in France: www.fnak.fr
- **Ministry of Higher Education and Research**: www.enseignementsup-recherche.gouv.fr
- **Oséo Innovation**, the French innovation agency: www.oseo.fr
- **Website for mobile European researchers in France**: www.eurosfair.prd.fr/mobility/

FRENCH RESEARCH PORTAL

WWW.CAMPUSFRANCE.ORG/EN/RESEARCHER

A UNIQUE, **ONLINE-ACCESS INFORMATION POINT**
FOR LOCATING RESEARCH PROJECTS



◆ UNDERSTANDING FRENCH RESEARCH

- > Understanding how PhDs operate in France;
- > Knowing how to start and finance a PhD;
- > Applying to international research programs (Hubert Curien Partnerships, *Make Our Planet Great Again*).



◆ DIRECTORY OF DOCTORAL INSTITUTIONS

Point of entry for starting a PhD and the 270 doctoral institutes organizing and supervising doctoral training.

- > Search by key words, regions, and disciplines;
- > Comprehensive information on doctoral institutions: Research areas, criteria and points of contacts for admission, welcome mechanisms, proposed topics, current financing, international dimension, and points of contacts for associated research laboratories;
- > Access to fields offered by each doctoral institutions.

30 doctoral schools in the energy domain accessible at :

<https://doctorat.campusfrance.org>



◆ PhD TOPICS, LABORATORY INTERNSHIPS, AND POST-DOCTORAL STUDIES:

- > Offers financed through doctoral contracts, Industrial agreements for training through research (CIFRE), and specific offers devoted to programs financed by foreign governments;
- > Offers for internships for experience in laboratory research;
- > Post-doctoral offers for work in French laboratories;
- > A detailed financing mechanism for each research offer (PhD topics, post-docs, and internships);

More than 50 offers made public in renewable energies each year, accessible at:

<https://doctorat.campusfrance.org/phd/offers>