The Development of Renewable Energy Sources for Electricity Generation: the Example of the French Overseas Departments and Corsica

Compared with the major interconnected power systems such as those in Europe, the systems of the French Overseas Departments and Corsica are quite different: from the electrical standpoint, they concern small isolated networks, because of their location on islands (Guadeloupe and Martinique, in the Caribbean, Reunion Island in the Indian Ocean) or not connected to neighbouring countries (French Guiana). The peak loads barely exceed 340 MW in the largest of these Departments (Corsica). As a result, the conventional generating facilities which may be used are costly (these facilities are mainly large diesel sets consuming heavy fuel oil). Furthermore, the late character of electrification and the fairly large dispersal of dwellings have still left a relatively high number of homes not connected to the power network. Finally, the potential of renewable energy sources in these territories situated in tropical regions and almost always volcanic is remarkably high, whether it involves hydroelectricity, wind, sun, biomass or geothermal energy. The interest of electricity generation sources calling upon these energies has thus increased considerably. Their development, in which ADEME (French Agency for the Environment and Energy Management), EDF (French Electricity Board), Groupe Charbonnages de France (CDF) and Compagnie Française de Géothermie (CFG) have taken part in particular, has been sustained and diversified.

Hydroelectricity

Historically, the use of renewable energy sources for electricity generation in the French Overseas Departments first concerned hydroelectricity: developed everywhere today except in Martinique, it provides more than 25% of the total output. As all of the major sites have already been harnessed, the recent facilities (Corsica, Guadeloupe and French Guyana) are mini hydro power plants with a capacity of a few MW and having a limited impact on the environment. New minihydro plants are forecasted for an estimated total of 20 MW, mainly in Corsica.

Biomass energy generation, bagasse as a fuel

Bagasse: an abundant and advantageous fuel, which is generally under-utilised

One of the main activities of the French Overseas Departments is the cultivation and processing of sugar cane. The sugar cane industry produces a residue called bagasse, which is the fiber of the cane after sugar has been removed. One metric to of cane produces about 320 kg of bagasse. Bagasse has a Net Calorific Value of 7900 kJ/kg which is greater than the NCV of many lignites mined in the world very expensively.

Bois-Rouge plant

Besides, compared to fossil fuels burned in conventional power plants, bagasse presents several substantial advantages:

- bagasse is a by-product, its use as a fuel would therefore seem economically more desirable than the use of fuel oil, natural gas or coal
- bagasse is issued from biomass; it is a renewable fuel and the CO^2 emissions from its combustion are offset by photosynthesis when sugar cane grows
- bagasse is sulfur free, no sulfur dioxides are produced when bagasse burns.

Traditionally, in most sugar cane mills of the World, bagasse is generally burnt in boilers in order to produce only the steam and the electricity needed by the mills. The least efficient sugar mills require yet another fuel (usually fuel oil) to meet their own energy needs, more efficient ones generate surpluses of bagasse (which then have to

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be disposed of), and the more modern ones generate surpluses of electricity exported to the grid, most of the time however the energetic efficiencies reached for the combustion of bagasse are modest compared to the results which could be obtained with more elaborated solutions. Bagasse is therefore an under-utilised resource of the planet. Every year 230 Million tons of bagasse are produced which are the energy equivalent of 45 Million tons of fuel oil or 75 Million tons of coal.

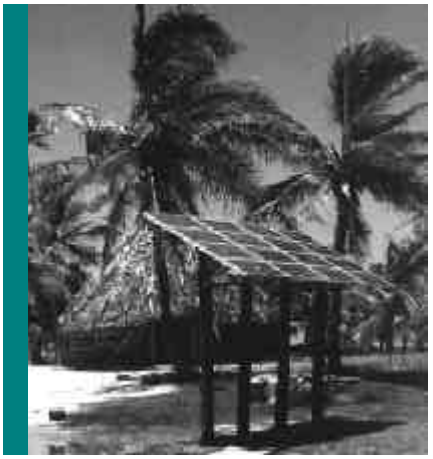
The Bois-Rouge Concept

In order to maximise the use of bagasse, a new type of Power Station was designed and built in Bois-Rouge (La Reunion). It was based on the application of the following principles:

- the Power Station in built next to the sugar mill in order to minimise transportation of bagasse
- the Power Station supplies process steam to the sugar mill and exports electricity to the grid
- The plant boilers generate efficiently (90 % thermal efficiency) high characteristics steam (80 bars, 520°C)
- in order not to store large quantities of bagasse, the Power Station burns all of the bagasse as it is produced by the sugar mill
- when bagasse is not available (mainly during the intercrop season which lasts six months) a second fuel is used, and the Power Station is operated as a conventional Power Station producing electricity for the grid
- the impact of the Power Station on the environment would have to be minimal (in particular as far as emissions are concerned)
- the plant would be operated by a company owned by SIDEC (subsidiary of Charbonnages de France), Industrielle Sucrière de Bourbon (sugar mill owner) and Electricité de France

The Bois-Rouge Power Station is made of the following equipment:

- two boilers producing each 130 tons of steam at 80 Bars abs 520°C, the two boilers can burn either bagasse or coal exclusively as well as any combination of the two fuels. Switching from one fuel to the other can be done on line automatically. The boilers are of the two drum multipass spreader-stoker type, with a two-stage superheater. Bagasse firing equipment is made on bagasse feeders that allow bagasse extraction and feed regulation from feed chutes. Coal feeders include slat conveyors and projecting drums located at the bottom of the coal chutes
- flue gas cleaning equipment made of two distinct dedusting systems: one mechanical deduster designed to collect large particles which will be reinjected into the furnace, the second stage consisting of an electrostatic precipitator
- bagasse handling system which includes an indoor storage of capacity 1000 tons needed to accommodate the different operating rates of the sugar mill and the Power Station, a set of conveyor belts and slat conveyors whose function is to carry an even quantity of bagasse to the boiler house
- coal handling facility including truck weighting, unloading, screening, grinding, two storage silos and a set of conveyor belts
- two turbo-generator sets of capacity 30 MWe each, consisting of two steam turbine each comprising a high pressure body and a low pressure body and a steam extraction system, two generators and two condensers
- two cooling towers aimed at cooling down the condensers, the lube oil plant and the generators
- ash handling system
- two water demineralisation units



The plant was commissioned in August 1992 and has achieved excellent results thence it was decided to build a second plant of the same type near Le Gol sugar mill. This plant was commissioned in the last quarter of 1995.

Bois Rouge and Le Gol Results

The main technical challenges faced by the engineers and the operators delt with:

- the size of the plants (circa 60 MWe each) compared to the overall size of the island grid (260 MW)
- the necessity to switch automatically from one fuel to the other
- the necessity to meet at the same time the demand from the grid and the demand from the sugar mill which could vary in totally different directions

These challenges were brilliantly met. Bois-Rouge and Le Gol power plants provide today 44 % of the total electricity produced on La Reunion Island, with an average availability of 90 %

Le Moule project

A third plant of the same type and of size 2 x 32 MWe has been commissioned in 1999 in La Guadeloupe near the town of Le Moule. With this project, bagasse available in the French Overseas Departments will be almost totally used to produce electricity and steam.

Geothermal

Geothermal production of electricity - Generalities

The production of electricity by geothermal energy demands high-temperature resources, essentially associated with current volcanic activity.

The world conference on Geothermal Energy at Florence in May 1995 reviewed the evolution of the production of electricity using geothermy on the whole planet.
This represents a significant market with a present installed power of 7045 MW and more than 700 MW under construction each year, which represents over a billion dollars in new projects annually world-wide. Despite a high investment of between 1200 and 2000 US$ per kW, operation and low-maintenance costs, generally representing between 10 and 20% of the kWh produced and a high availability of about 8000 h per year, make this form of energy extremely competitive at between 5 and 8 US cents per kWh for a minimum installed capacity of 10-30 MW.

Geothermal Production of electricity in the French Overseas Departments: Guadeloupe, Martinique and Reunion

The production of electricity by geothermal energy in the French Overseas Departments presents certain advantages:

- an attractive production cost: an island context means that geothermal energy production costs compare advantageously with those of standard production, even for small installed capacities,
- geothermal energy uses local resources and has no greenhouse effect,
- geothermal energy is a significant potential resource at regional-demand scale:

Guadeloupe: a 5 MW pilot geothermal plant was constructed and brought into operation in 1986 by EDF. Following recent renovation work, it is now operated by a private company, combining CFG (subsidiary of the BRGM [Bureau de Recherches Geologiques et Minières]) and Charth (EDF subsidiary). An availability rate of around 90% over the first years makes this plant highly promising. A minimum of 20 MW can probably be installed at the Bouillante site, i.e. 12 % of the island's peak demand, 15 % in produced energy (base operation), and exploitation of a further site seems foreseeable. CFG has been carrying out research since 1995 on

these two points and on the successful installation of 40 MWe. The drilling phase for the extension to 20 MW of the pilot plant will begin during the 2nd semester of 1999.

Martinique: 5 MW could be installed in a first phase at the Lamentin site with, if possible, 10-20 MW during a second phase. Three zones show promising indications. Development includes an exploration drilling phase that is scheduled to begin in 1999.

Reunion: 20 MW could be installed when the demand currently met by the bagasse-coal plants need the installation of supplementary production means (2006). Two deep exploration boreholes were drilled in 1985 at the Grand Brûlé and Salazie sites. Although non-productive, these boreholes and associated studies have shown that potential exists for discovering exploitable high-temperature resources, especially at Salazie. It should be noted that in Hawaii, six boreholes were put down before a resource of 358°C was found at 2100 m depth.

The Bouillante plant in Guadeloupe: an example reproducible in the Caribbean

The original specifications drawn up at the start were retained during the renovation work. They are based on:

- automation enabling the plant to be operated by five people that permanently monitor the smooth running of operations via an assistance network.
- daily remote transmission of the main operating data to a dependable, but external, technical unit, located in this case more than 5000 km away. This unit periodically interprets the operating data. A permanent dialogue thus exists between the plant and the external technical unit, which must be able to intervene rapidly upon request. It intervenes in the same way for other geothermal sites elsewhere, also external.
- integration in a difficult environmental setting.

This plant is sufficiently soundproofed that normal operation is imperceptible outside the plant site, even though this plant, originally built on the urban outskirts, is now contained within the built-up-area. Total steam condensation also removes any visual impact of the plant's operation. A return of sea water at 40°C in an area of natural, major and very hot (70°C) submarine springs completes this environmental integration, assisted by the fact that the geothermal fluid at Bouillante (and that of its springs) is a 50-50 mixture of sea water and meteoric water infiltration without specific chemistry. The H_2S content is very low and a trapping system is currently being installed.

Other projects in the Caribbean

The Caribbean basin is an area of active volcanism that, since the 1950s, has enabled the production of electricity by geothermal energy to be developed along the western margin: 1039 MWe are already installed, including 793 MW in Mexico, 105 MW in Salvador, 70 MW in Nicaragua and 70 MW in Costa Rica.
The eastern margin, constituted by the Caribbean volcanic island arc, was subject to an inventory that revealed several areas of interest, the main ones being the islands of Nevis, Montserrat, Guadeloupe, Dominica, Martinique, Saint Lucia and Saint Vincent. Drilling was carried out in Saint Lucia and Guadeloupe in the 1970s following work carried out by BRGM.
The Bouillante plant in Guadeloupe is an example of the integration of a small electricity production unit and demonstrates that geothermal energy is a mean of producing electricity in the Caribbean and in volcanic islands in general, specific areas that have in common:

- a favourable geological setting for significant geothermal resources,
- relatively high costs for conventional production methods,
- a favourable environmental setting for the siting of small electricity production units with low impact.

Wind Energy

Specific technological difficulties in the Caribbean islands

Although the wind resource (trade winds) is quite high in the Caribbean islands, the use of wind power to produce electricity has not been developed in these islands until very recently. It is mainly because in the past a certain number of technological difficulties have inhibited any real development of this source of energy.

The logistics and technology of the wind power stations in the Caribbean have nothing in common with what exists in Europe or the State. It seems difficult to get a 40 to 60 metre high crane carrying several tons around the islands where the access roads often have a limited capacity.

The Caribbean is often hit by hurricanes, which could up beyond repair the type of machines designed for the milder climates in Europe or the States.

The maintenance and up-keep of the wind machines must be possible without any special equipment and with properly trained local workers.

Even more restricting is the fact generating wind energy on a diesel grid is only of interest if it represents a major part of the energy consumed altogether. However, the machines on offer from the main builders only allow between 10 to 15 % of the petrol consumed to be replaced by wind energy.

Furthermore, the diesel grids in the Caribbean islands often work in a rather haphazard manner with frequent power cuts.

Wind machines adapted to the Caribbean context

If the machines on offer from the European of American constructors are not adapted to this context, they have nonetheless led to major technological breakthroughs on the wind power front with the development of low or medium power wind machines which are perfectly adapted to the Caribbean context: the wind generators produced by VERGNET CARAIBES.

No particular equipment is needed for the installation and maintenance of these machines: they are mounted on post that can be lowered with just a winch or a "tirfor" that is motorised hoisting gear.

These machines have been designed in such a way so that a locally trained mechanic can maintain them.

The maintenance of the Guadeloupean equipment is made so easy by the original technology behind the mechanical speed control mechanism.

Their exceptional ability to withstand high winds and sea spray and the possibility to lower them if a violent hurricane is on the horizon means that their permanent installation can be envisaged in the Caribbean.

Lastly, the technology developed by VERGNET CARAIBES for Guadeloupe's wind turbines allows them to coast along which means that they can contribute relatively highly to to energy produced on the diesel grids, even if they are of mediocre quality. Up to 60 to 70 % of energy can be generated by wind turbines.

This technology, perfected in Guadeloupe, with materials manufactured here following studies carried out by VERGNET CARAIBES, is behind the development of low and medium powered wind power stations, that is with turbine units of between 10 to 60 kW and soon with 200 kW turbines units.

The price per kWh is already competitive compared to the price of a kWh produced from fossil fuels.

Realisations

The first wind power station, on Desirade island (off Guadeloupe) up and running since 1992 shows VERGNET CARAIBES' Guadeloupean technology potential for adaptation and competitiveness.

In the beginning the Desirade wind power station's capacity was 140 kW, this has been increased to 500 kW which covers all of the island's energy needs.

A second wind power station with a 1.5 MW capacity has been commissioned at the end of 1997 on Marie-Galante Island (also off Guadeloupe).

The other projects for Antilles (Martinique and Guadeloupe) with a total capacity of 12 MW have been approved for financement in the frame of the Eole 2005 Programme.

This new wind energy technology from and for the Caribbean is of interest for all the region and some projects are already underway in Santo Domingo, studies are being carried out in Haiti and the Grenadines and Cuba has already shown an interest. The studies of this natural resource, the manufacture, installation, training and maintenance, even the management of the power station are all available in Guadeloupe.

Development under progress: Corsica

The technical potential of wind energy in Corsica has been identified: 433 MW for annual average wind speed higher than 7 m/s. On this base the economical potential is estimated at the level of 100 MW. In the frame of the Eole 2005 programme, 11 projects have been approved for a total of 52 MW. The first realisation is planned for the end of 1999.

Solar Energy

There are several thousands of dwellings which are located in remote places in

Corsica and in the French Overseas Departments, and therefore not connected to the grid.

A very significant number of these dwellings, and also farm installations, pumping stations... have been fitted with photovoltaïc systems: at the end of 1998 their total number reaches almost 4000 and the total installed capacity is about 4 MW. It is worth noting that the "PV density" of the French Overseas Departments, defined as the number of Wc per inhabitant is probably one of the highest in the world. The population of these Departments being close to 1.5 millions, their PV density is about 2.5 Wc per inhabitant.

The unit installed PV capacity is quite high (about 1 kWc). Even when excluding professional uses, the unit installed PV capacity in each dwelling is still high especially when compared with Solar Home Systems in developing countries, the unit capacity of which is typically in the order of magnitude of 50-100 Wc. This high unit capacity is necessary because of the substantial amount of electricity services necessary for relatively high-income populations. It in turn necessitates high quality installations, sophisticated energy management and very good reliability. The main operators in this field are the companies Solelec-Caraïbes and Solelec Reunion, subsidiaries of Total-Energie. CHARTH acquired a 35% stake in the share capital of this firm in 1996.

Solar energy is also used on a large scale in its thermal form, for the production of hot water in solar water heaters as a substitution for the use of electricity. At the end of 1998, the total number of solar water heaters reaches 40.000 compared to a total number of dwellings of about 650 000.

More than 10 000 solar water heaters have been sold during the last two years. In this field too, a great emphasis has been put on quality and reliability, with maintenance contracts up to 10 years.

Conclusion

Renewable energies provide about 35% of total electricity generation in the French Overseas Departments and 40% in Corsica. Combined with major electricity demand side management programmes in these Departments, their use makes it possible to substantially reduce electricity generation based on petroleum products in conventional thermal plants, with a triple benefit:

- from the environmental point of view, a substantial reduction of global (CO_2) and local (SO_2, NOx, dust...) pollutants
- from an economic point of view, a significant reduction of generation costs (partially due to the tax exemptions schemes which exist in these Departments in favour of renewable energies)
- from a societal point of view, the use of renewable energies instead of imported oil provides more jobs locally, in Departments which are heavily struck by unemployment. Besides that, people living far from the electricity grid can now benefit from electricity services provided by the above mentioned PV-electrification programs.

All the corresponding techniques have been adapted to the difficult climatic characteristics of these Departments (hurricanes, substantial rainfall, air that is hot, salty and extremely damp, and therefore very corrosive in the islands), and are available locally, which means they can be readily used without additional adaptation in other tropical or Mediterranean regions, in particular those in the area of the French Overseas Departments, where electricity supply is provided under similar conditions: islands of the Caribbean and the Indian Ocean, and the Amazon region.

The Renewable Energy development in the island's context is a real success story. The RE technologies have proved their reliability and their economical competitivity, notably with the concept of long period plant management by private operators and energy sales to the users.

Considering these results, ADEME has proposed to the French Government a Renewable Energies Development Program 1999 - 2006 adapted to the continental context.

The energetic targets for 2006 are the followings:

- **Biomass:**
  - + 200.000 tep in collective dwellings and tertiary sector
  - stability at 8 Mtep in individual dwelling sector with efficiency improved by 10 %.

- **Electricity from renewable energy sources**

  Wind:
  - + 500 MW (1.2 to 1.5 TWh/ky)
  - + 3.000 MW in 2010.

  Small hydro:
  - + 100 MW (0.5 TWh/y).

  Photovoltaïc (grid-connected and off-grid):
  - + 10 MW

  Geothermy:
  - + 25 MW (0.150 Twh/y)

- **Heating and hot water:**

  Geothermy:
  - + 10.000 equivalent dwellings (5.000 tep).

  Solar thermal:
  - + 85.000 Solar Domestic Hot Water Systems
  - + 35.000 m² in collective/tertiary
  - + 1.500 Solar heatings of individual dwelling.

The targets are also to enhance the economical competitivity of Renewable Energies technologies and to support the development of a strong professional sector, industrialists, engineering companies, installers…

To reach these objectives, a set of financial measures will be notified in the next weeks to the European Union Commission.