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RENEWABLE ENERGY IN RÉUNION: POTENTIALS AND OUTLOOK

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Renewable Energy in Réunion: Potentials and Outlook

JULIEN BADDOUR* and JACQUES PERCEBOIS**

Abstract:

Renewable, environmentally friendly and evenly distributed across the globe, renewable energy (RES for Renewable Energy Resources) is an excellent means of taking up the global energy challenge, i.e. enabling developing countries in the south to make progress without harming the environment. Since it is particularly well suited to an island territory's character and local needs, RE is also an excellent tool that could enable France's Overseas Departments and Territories to reduce their energy dependence, preserve their environment and ensure their sustainable development. In Réunion, RES benefit from marked political support and from a very favourable financial and institutional environment, which has allowed the Réunion region to become a national pioneer in the realm of thermal energy and photovoltaics. Nonetheless, RES are not a panacea as they are subject to a number of flaws. It is currently expensive and uncompetitive, intermittent and insufficiently powerful, and not always available to keep up with demand. This explains why RES cannot aspire to be a complete substitute for fossil fuels. The two energy systems complement one another to meet the region's total energy needs. This article also highlights the negative consequences of the support measures for RES (inflated costs and negative prices on the electricity markets) and underscores the need for a complementary energy policy in pricing electricity, as well as effecting energy savings, which must remain our priority.

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Renewable energy sources, due to an ability to reconcile the demands of energy, environment and sustainable development, will be required to develop exponentially over the 21st century. However, the interest in renewable energy does not stop there. The current global energy crisis and the threat of a more or less rapid depletion of fossil resources are lending strength to the appeal of forms of energy considered inexhaustible, at least on a human scale.

For island territories, renewable energy takes on a very specific importance. On the one hand, the insular nature of the territories compels them to rely upon local energy resources, since they cannot connect to an outside supply network while on the other hand, local renewable energy is aptly suited to decentralised production in isolation and to the small size of these territories.

As a result of its geographical and climatic conditions, and its wealth of renewable energy resources, Réunion, like France's other overseas departments (DOM) and overseas territories (TOM), constitutes an ideal setting for using and exploiting renewable energy sources. Devoid of fossil energy resources (oil, gas and coal) and currently facing a stark increase in its energy consumption, the rise in imported fuel prices and the effects of climate change, Réunion is making investment in renewable energy a priority in order to bring about a sustainable solution for what is an alarming energy situation.

As early as the year 2000, the Réunion Regional Council developed and put into effect the PRERURE programme (Regional Plan for Renewable Energy and the Rational Use of Energy). By making a priority of managing demand for energy and developing renewable energy sources, Réunion hopes to approach self-sufficiency in energy production by 2025. The search for energy self-sufficiency through ambitious programmes of saving energy and promoting renewable energy is frequent in developing countries with a good supply of solar power (cf. H. Lund 2007), but it is also beginning to emerge as a concern in industrialised nations. This is the case for instance of certain RE advocates in Denmark who hope to reach energy self-sufficiency by 2030-2050, thanks to renewables. An article by H. Lund and B.V. Mathiesen (2009) demonstrates that this is technically possible, but that it is very complex to bring about in practice.

In spite of its intrinsic advantages (energy which is inexhaustible, diversified, non-polluting or very little, better suited to decentralised production and to local needs with multiple and variable uses), the development of renewable energy remains rather limited at the moment, as evidenced by its modest share in the national and regional energy system. This is doubtless because today's sources of renewable energy are expensive and uncompetitive, intermittent, of low power, dispersed and not always available according to demand.

In this context, certain questions spring to mind. Does renewable energy have the potential to allow Réunion Island to achieve energy self-sufficiency by 2025? What obstacles stand in the way of its development? Which measures should be favoured by the authorities to promote renewable energy with a view to energy self-sufficiency? We shall first examine the true potential of Réunion in renewable energy and the extent of its development. Secondly, we shall make an inventory of Réunion's energy and its history. Finally, we shall evoke the obstacles which are impeding the development and extension of these forms of energy.

I. Réunion's potential in renewable energy and its state of development

I.1. The ecosystem of Réunion Island is rich in renewable energy sources

Since the espousal of the concept of sustainable development by the Rio conference in 1992, renewable energy has experienced a notable rekindling of interest which is strengthening each year. Renewable energy sources, the first used by man, are essentially drawn from nature - earth, water, air and fire, but also from the sun – and their use does not in any way imply the depletion of the initial resource. Réunion is very rich in such sources. Its ecosystem, more than the other islands in the Indian Ocean, provides it with a vast and diverse supply of renewable energy sources.
An island of volcanic origin, Réunion is 70 km long, 50 km wide and reaches an altitude of 3069 m. It is characterised by a very mountainous and difficult terrain and has one of the highest rainfalls in the world, which explains the importance of **hydropower** on the island. Réunion is also dependent on the Mascareignes Anticyclone whose permanent centre is on the south-east of the island. The wind conditions are characterised by a period of marked trade winds from east-south-east to the south-east during the southern hemisphere winter between May and September. This should facilitate the existence of sites favourable to the production of **wind power**.
Réunion also has a volcanic environment favourable to the existence of **geothermal resources** as evidenced by the island's active and quiet volcano, le Piton de la Fournaise ("Peak of the Furnace"), as well as the existence of a thermal site today in the Cirque of Cilaos and in the past another in the Cirque of Salazie. There is probably a vast geothermal treasure hidden beneath Réunion's earth, and the Réunion Regional Council is currently prospecting this.
As it benefits from a tropical climate, **solar power** on Réunion is without doubt a source of considerable potential. The average number of sunlight hours is generally very high and better distributed over the year than in metropolitan France. Finally, in spite of a breathtaking mountainous terrain alternating sharp peaks, egocentric cirques and sheer cliffs, nature also offers acres of sugarcane fields, a plant providing **biomass** which represents a considerable source of energy.
To sum up, the great density of forests and the nature of the land, the diversity of endemic vegetation, the gigantic forces of fire, wind and water and the tropical climate make the Réunion ecosystem a natural environment favouring renewable energy sources.

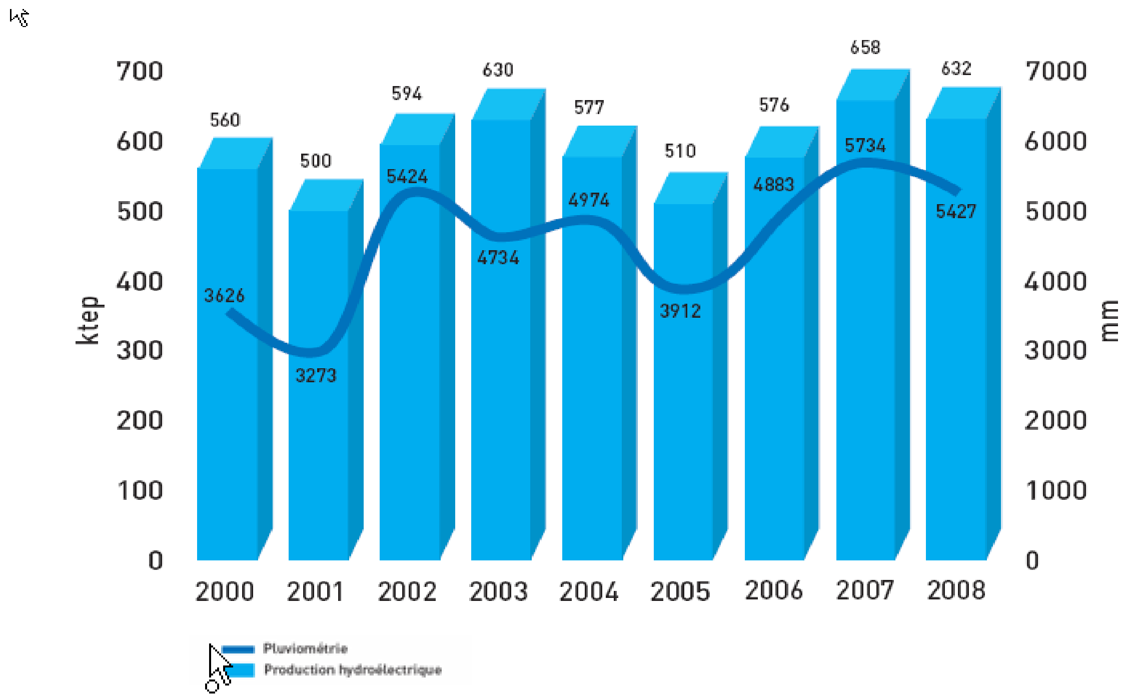
I.2. An apparently considerable potential for sustainable energy resources, but one which is not always exploited

Réunion's biodiversity is very rich in renewable energy of all kinds. Among them we may discern guaranteed and seasonal energy sources which have already been exploited for some time (hydropower and biomass), intermittent energy sources exploited more recently (solar and wind power) and energy sources currently undergoing experimentation (geothermal energy, wave power, ocean thermal power and off-shore wind power, etc.).

I.2.1 Guaranteed and seasonal renewable energy sources which have already been exploited for a long time

a. **Hydropower:** Hydro-electric energy is the oldest and best exploited source of energy in Réunion and also worldwide. It has the advantage of being a powerful renewable source of energy, but is also unstable as it is highly dependent on rainfall and has no potential for expansion. Whereas in 1981 hydro-electric energy covered almost all of the island's electricity needs, in 2008 it only provided 24.5% of its needs. Dependent on rainfall, this source suffers from the fact that it can vary perceptibly between the cyclone season and the dry season (see figure 1) and that it may at times put the island's fresh water at risk. Indeed, there are occasional tensions between the energy and non-energy uses of water (drinking water supply, irrigation).

Figure (1): The evolution of hydroelectric production and rainfall from 2000 to 2008.



Source: Réunion Island Energy Observatory (OER) (2009).

b. Biomass

Due to its tropical climate and its soil's mineral wealth, Réunion island possesses a vast and important potential for biomass. Different types of biomass resources exist on the island: bagasse, household waste, livestock effluence, green waste, sewage treatment plants, forests and vegetation. Réunion is the first region in the world to have exploited bagasse, the fibrous residue produced by the process of refining sugarcane, established in 1992. There are two coal-bagasse thermal power stations: the Gol power station (122 MW) in Saint Louis and the Bois Rouge power station (108 MW) in Saint André. In 2008 the proportion of electricity produced from bagasse was 10.3%. The fluctuation of its share in the production of electricity depends mainly on the quality of the sugar season which in turn depends greatly on climatic factors.

Furthermore, this system of energy production could face problems such as dispersion and the limited size of the sites capable of generating biomass resources. The risk of a decrease in sugarcane production in future as a result of the termination of European subsidies allocated to this plant, as planned from 2013, poses a threat to this source of energy.

I.2.2 Intermittent renewable energy sources recently put into use

a. Solar energy

Solar energy constitutes the greatest potential of Réunion in terms of renewable energy as the island benefits from excellent year-round exposure to sunshine, although insolation varies from one area to another according to altitude and cloud cover. A marked expansion in the solar-powered water-heater market has been noted over the last few years, as well as grid connected solar panels. Solar energy is therefore exploited as thermal energy and as electrical photovoltaic energy (PV). However, for the time being there is little interest in the development of thermo-solar power stations (Concentrated Solar Power, CSP) since, unlike photovoltaics, thermo-solar energy requires intense exposure to sunshine, and this exposure is often clouded in Réunion.

- **Thermal solar energy** heats liquids or solids. It can be used to heat the pool, for air conditioning and the production of hot water for sanitation. In Réunion the most utilised system is the solar water-heater (SWH), which captures energy from light to produce hot water for sanitation in a collective or individual residence. Since 2003, SWHs have been widely implemented across the island. On average, about 10,000 SWHs are installed each year, which equates to a saving of about 25 GWh. According to the OER (Réunion Island Energy Observatory), at the end of 2008, there were 94,839 individual solar water heaters installed on the island. This equates to a thermal production of 142.3 GWh.

- **Photovoltaic solar energy:** In Réunion, there are two photovoltaic solar systems:

  - **Solar panels in remote areas**: the nature of the island's terrain is conducive to the installation of solar panels in remote areas. This new mode of production has allowed electricity to be brought to the remote dwellings of Mafate and to homes at the extremity of the electrical network. Between 1996 and 2006, such installations in isolated areas numbered 641 for 649 KWc.

  - **Grid connected solar panels**

At the launch of the PRERURE programme in 2003, the Réunion Regional Council set as its objective the connection of 5 to 6 MW of PV to the network each year. Although this goal has suffered some delays, there has been a real explosion in the market for grid connected PV generators since 2006. Grid connected photovoltaic power is a form of energy whose power production is susceptible to stark variations from one moment to the next and, what is more, is not available for the evening peak. According to EDF Réunion, the number of PV production hours on the island is gauged at 1,300 of the 8,760 hours in the year. In 2008, Réunion established France's largest structural photovoltaic installation, the CILAM farm in Saint Pierre (2 MW). The island also installed France's largest ground-level photovoltaic farm at the end of 2009 in Sainte Rose (13.5 MW). In 2007, the island occupied third place on the European scale and according to the Réunion Island Energy Observatory (OER) it held **first place in Europe** in early 2010. Spain is lined up to take over its position, however, since besides CSP type power stations, that nation is also building PV stations on a grand scale.

It is noteworthy that solar panels have variable production according to latitude and cloud cover, and one which drops off entirely overnight. Thermal solar power is subject to the same constraints but to a lesser extent, as storing thermal energy is simpler (including on a large scale in the form of molten salt). Locally, this source of energy also suffers from the high costs associated with grid connected PV, as well as complicated assembly.

b. Wind power

As for photovoltaic energy, wind power is a form of energy which cannot provide a guaranteed supply of power to the network. As a result, it offers only marginal savings for the investment as opposed to standard production methods which can be mobilised in real time to confront these considerable fluctuations. On the other hand, these methods of production, in spite of their fluctuating supply, do produce energy which serves to decrease the share of fossil fuel required for the grid. According to EDF Réunion, in terms of the quantity of energy produced, the number of equivalent full power hours is estimated at 1400 in Réunion. The rate of availability is thus not very high. Nevertheless, in 2008, the Sainte Suzanne and Sainte Rose wind farms produced 13.5 GWh with a power yield of 16.4 MW including 6.1 MW yet to be put to use. Generally speaking, this energy is criticised for being subject to stark variations according to wind speed. What is more, at a local level, this sector carries a number of disadvantages such as:

- the visual and auditory impact of the wind turbines
- the far from optimal natural conditions in Réunion (limited space, tropical cyclones, irregular wind availability). On this point, it is important not to confuse intermittency and unpredictability. Intermittency poses the problem of the investment to be foreseen in terms of backup solutions to face the average unavailability of wind power. Unpredictability poses management problems, the exploitation of the various power stations in real time as a result of insufficient winds at any given time (cf. J.P. Hansen and J. Percebois, 2010).

I.2.3 Renewable energy sources undergoing experimentation

There are multiple sources of renewable energy currently undergoing experimentation. According to GERRI (Green Energy Revolution: Réunion Island), all of these forms of energy are available, and in the most promising of contexts. Examples include geothermal energy, wave power generation, ocean thermal energy conversion, off-shore wind farms, etc.

I.2.4 The intermittent character of some forms of renewable energy constitutes an obstacle to their development on the island

According to EDF Réunion, integrating intermittent energy dependent on wind or sun into a small remote electric grid is technically far more problematic than doing the same thing on a large continental network, and it brings with it a significant risk of black-out. In order to ensure the security of the electricity supply, a government decree from 2008 (article 22 of the act dated 23 April) fixes the maximum production of intermittent energy to be mustered on the island grid at any given time at 30%. According to EDF Réunion, high capacity storage could help to overcome this obstacle.

II. Réunion offers very favourable political, institutional and financial conditions for the development of renewable energy

II.1. A favourable institutional framework

Renewable energy sources have benefited from marked support from the public authorities over the last ten years, from the European Union as well as at a national or regional level. The EU supports the development of renewable energy and the rational use of energy, as its research programmes (such as the Alterner programme) and its financial structural funds (ERDF, European Regional Development Fund) make evident.
The French State applies this European directive to the French territory through several legislative means:

- The act pertaining to the modernisation and development of the public service of electricity dated 10 February 2000, which obliges the network's management to put in place, under State's control, a multi-year investment plan.
- The guidance law of 4 February 1995 pertaining to spatial planning and development (the Voynet Act or LOADT), which aims to facilitate and emphasise the contribution of Territorial communities to the national energy policy and to the Territories' sustainable development by determining the way in which they can support actions of energy control and the production and use of renewable energy.
- The Pons Act and later the Paul Act pertaining to tax exemption benefited RE businesses and were instrumental in expanding the SWH market in Réunion.
- The overseas guidance law of 13 December 2000 delegates the authority to the Réunion Regional Council to plan for the exploration and exploitation of renewable energy sources and for the rational use of energy.
- The programme act 2005-781 of 13 July 2005 establishes the guidelines for France's energy policy over the coming years. Its objective is to reduce CO_2 emissions by 75% by 2050 and to satisfy 10% of energy requirements and 21% of electricity production through the use of renewable energy sources by 2010.

II.2. Unquestionable political resolve

In Réunion, Mr. Paul VERGES's accession to the presidency in 1998 and the new overseas guidance law have greatly contributed to the repositioning of RE at the heart of the regional government's economic policy considerations. This has been revealed on a political level by Paul VERGES's speech to the United Nations and UNESCO in which he evokes Réunion Island's self-sufficiency in clean and renewable energy. On a practical level, it has meant renewing geothermal and wind power prospection programmes, by creating the Réunion Island Regional Agency for Energy (ARER) and the Réunion Island Energy Observatory (OER), and by creating and implementing the Regional Plan for Renewable Energy and the Rational Use of Energy (PRERURE) since 2002.
This plan has three main objectives:

- To encourage the development of renewable energy and the rationalisation of energy consumption in Réunion with a view to attaining its electrical energy self-sufficiency by 2025 (see table 1)
- To reduce greenhouse gas (GHG) emissions on the island
- To develop local employment through the creation of new job opportunities.

Two means of achieving these goals are:

- Promoting a voluntarist policy of energy efficiency in order to slow the current dynamics of increasing energy consumption

– Prioritising renewable energy sources (to the detriment of fossil fuels) when developing new projects for intensifying electricity production.

II.3. Unequivocal financial support

The cost of implementing the PRERURE over the period 2002-2025 is close to a billion euros. The public funding share has been estimated overall at 40% of investments. Public funding is composed of funds from the Regional Council, from the ADEME, from EDF, from the State, from the European Union and other public and private organisations or establishments (see table 1)

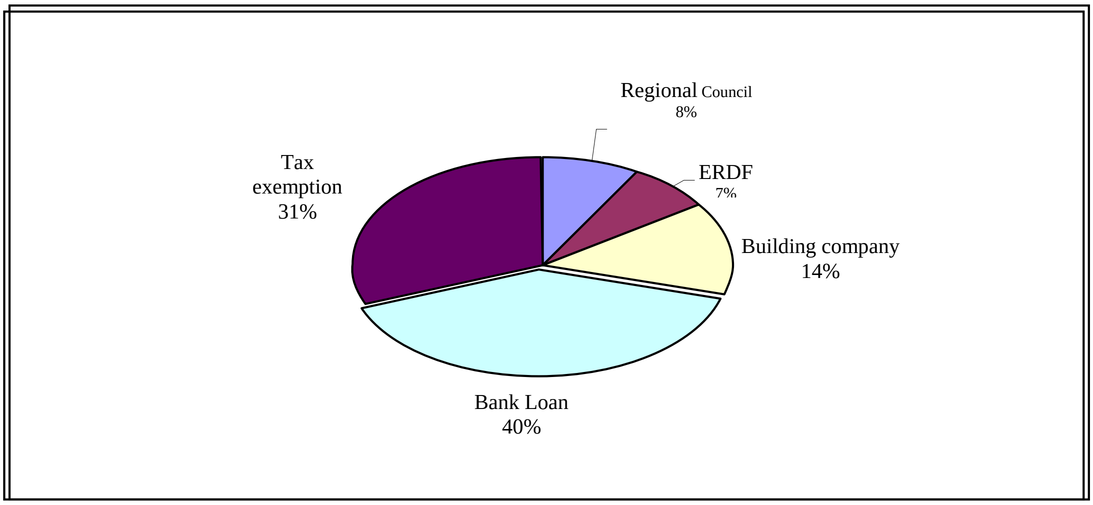
Table (1): Total cost of the PRERURE in millions of euros

	Total investment in millions of euros	Cost for public institutions	Power in megawatts
Cost of the RES programme	700	280	370
Cost of EDM	180	72	
Cost of the fossil programme (included in PRERURE*)	120	48	90

Source: PRERURE
*Cost of investing in standard thermal equipment to ensure a balance between supply and demand.

Another example showing the deep commitment of local authorities in funding projects pertaining to renewable energy is that of the Sainte Suzanne wind farm, inaugurated on 8 November 2006, (see figure 2)

Figure (2): Composition of financing for the Sainte Suzanne wind farm



Source: OER

As we can see, tax exemption on production investments in Réunion, as introduced by the Pons Act and modified by the Paul Act, is one of the main factors contributing to the development of renewable energy sources in Réunion. The example of the Sainte Suzanne wind farm shows that the financing for operations related to renewable energy is generally quadripartite. A building company brings a part of the funds invested while benefiting from

30% tax exemption. Private financing is supplemented by European structural funds and national funds.

III. Réunion Island's energy balance

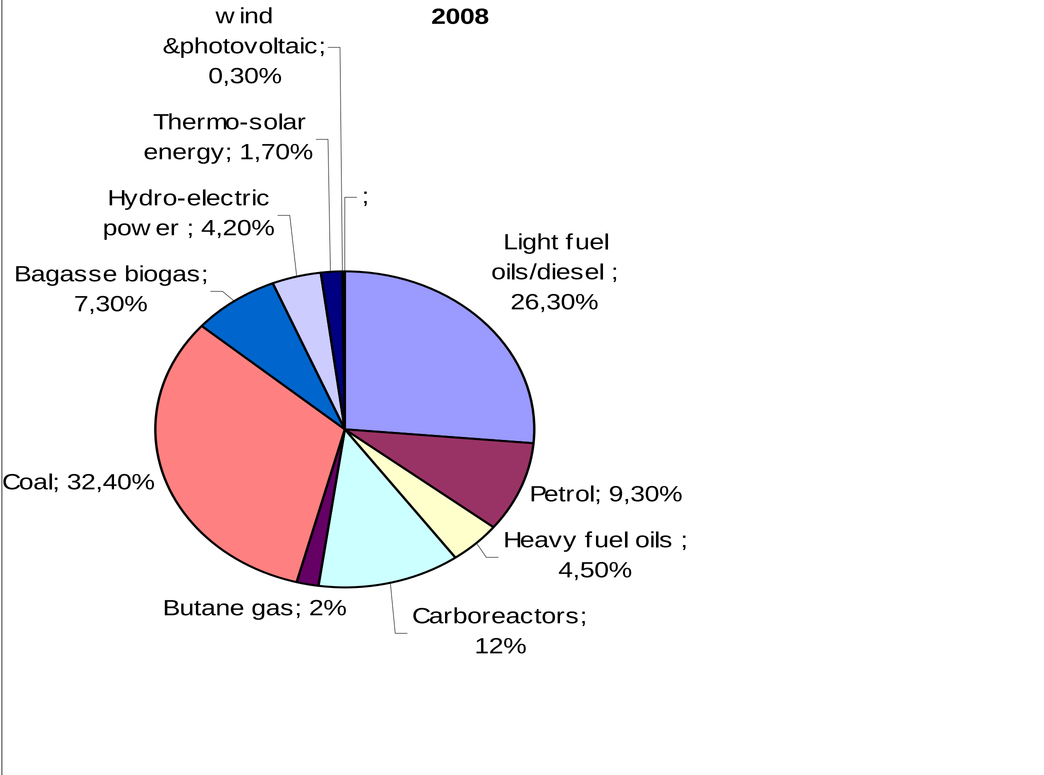
Réunion Island is France's most densely populated overseas department with 800,000 inhabitants in 2008 over 2512 square km. By 2030 its population should grow to more than a million. This territory has also demonstrated an average annual economic growth of 5% for over 30 years. As a consequence, drastic growth in primary and electric energy consumption has ensued.

III.1. Primary energy balance

Primary energy is the raw energy which must be converted before it can be used (oil, gas, coal, nuclear, water, wood, etc.). Final energy is the energy supplied to the final consumer (petrol, electricity, etc.). The consumption of primary energy measures a country's energy dependence rate, whereas the consumption of final energy allows the calculation of the penetration rate of any kind of energy for a given usage.

a. In the short term, the primary energy consumption (PEC) of the Réunion people was established at 1,295 ktoe in 2008. 13.5% (175 ktoe) of this consumption is supplied by local production (hydropower, bagasse, solar, wind), and the rest, i.e. 86.5%, by imported fossil energy (see figure 3) The primary balance shows a very small proportion of renewable energy and a predominance of imported fossil energy (oil products and coal). It also shows the high energy dependence of Réunion in terms of currently imported forms of energy.

Figure 3 : The distribution of primary energy consumption in 2008

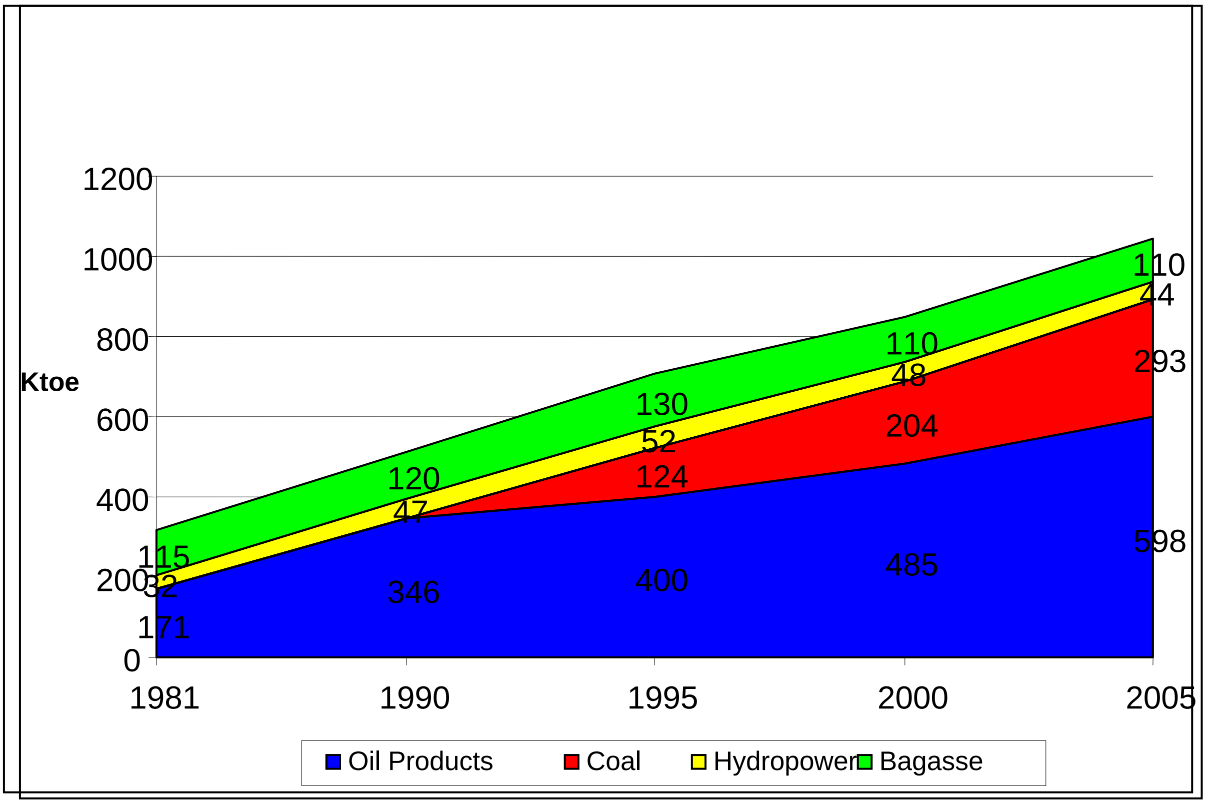


Source: OER

b. The long-term view

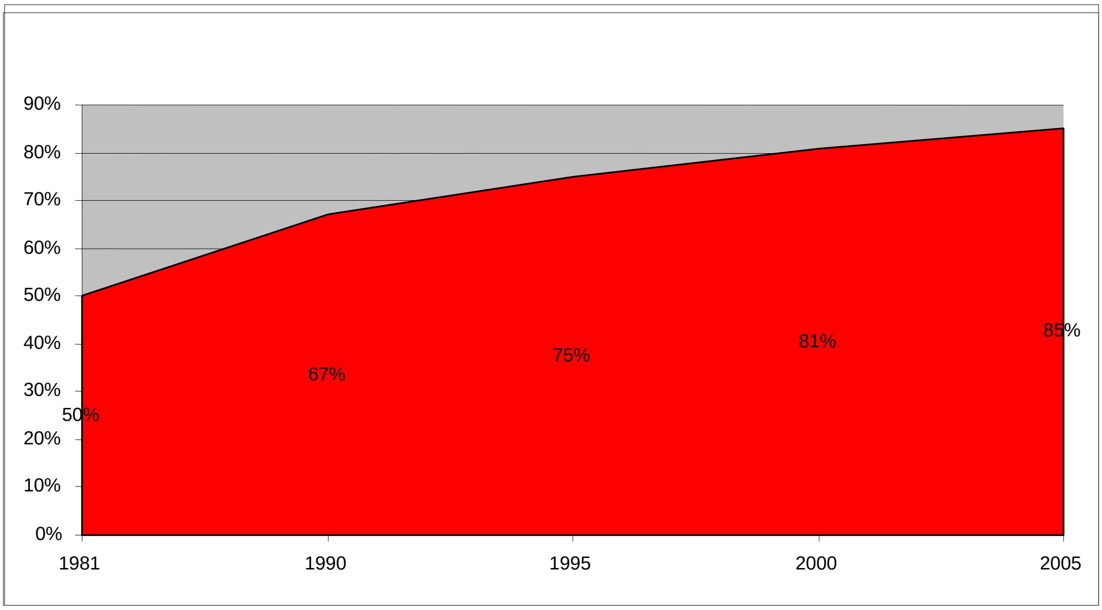
Réunion's energy landscape has changed drastically in 25 years. Whereas the island's primary energy consumption did not exceed 340 ktoe in 1981, it reached 1,295 ktoe in 2008, that is to say an over 300% rise. The island's demographic dynamics, the explosion in the number of cars on the roads, the rapid development of the residential and tertiary sectors, the raise in the people's purchasing power and the population's access to modern household conveniences are the principal factors behind this energy increase.
It can also be seen that the island's increase in primary energy consumption was not accompanied by a parallel increase in local energy production. The level of local production has remained practically identical in 25 years (154 ktoe in 2005 versus 147 ktoe in 1981). The abyss between the growth in primary energy consumption and that of the island's energy production has increased its energy dependence on the outside world. In 25 years, the contribution of renewable energy to the primary energy balance of Réunion has fallen from 49% in 1981 to 13.5% in 2008. The rise in the island's energy requirements has therefore been almost entirely satisfied by fossil energy imports, (see figures 4 and 5)

Figure (4): The evolution of primary energy consumption in Réunion between 1981 and 2005



Source: OER

Figure (5): Energy dependence ratio of Réunion Island between 1981 and 2005



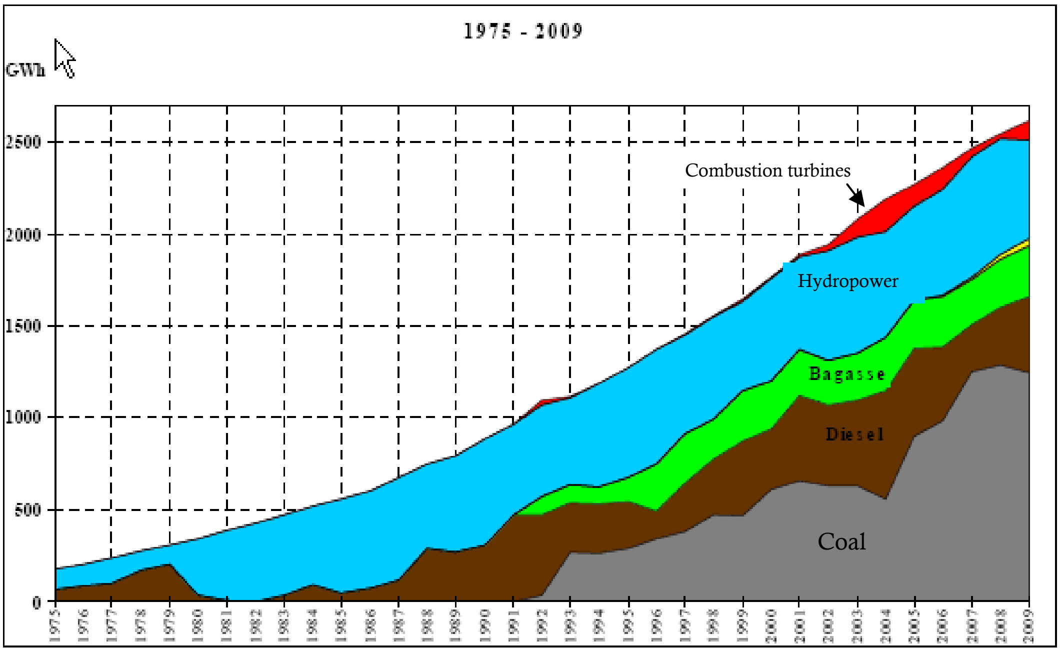
Source: OER

III.2. Assessment of Réunion Island's electricity system in 2008

III.2.1 Historical background

In 1982, almost all of the island's electricity requirements (99%) were covered by local production thanks to its hydro-electric power plants (see figure 6). From the mid-1980s, as a result of its historical dynamism and the advent of the consumer society, the island's electricity requirements grew considerably, forcing it to resort to oil and coal imports. Since then, its dependence on imported fossil energy has continued to grow in spite of the development of bagasse exploitation in the 1990s and the current development of wind and photovoltaic energy sources. In 2008, the share of renewable energy reached 36% thanks mainly to hydro-electric energy (24.86%) and bagasse (10.31%).

Figure (6): The evolution of electricity production between 1975 and 2009 in Réunion



Source: EDF Réunion (2010)

III.2.2 Electricity supply and demand in Réunion Island in 2008

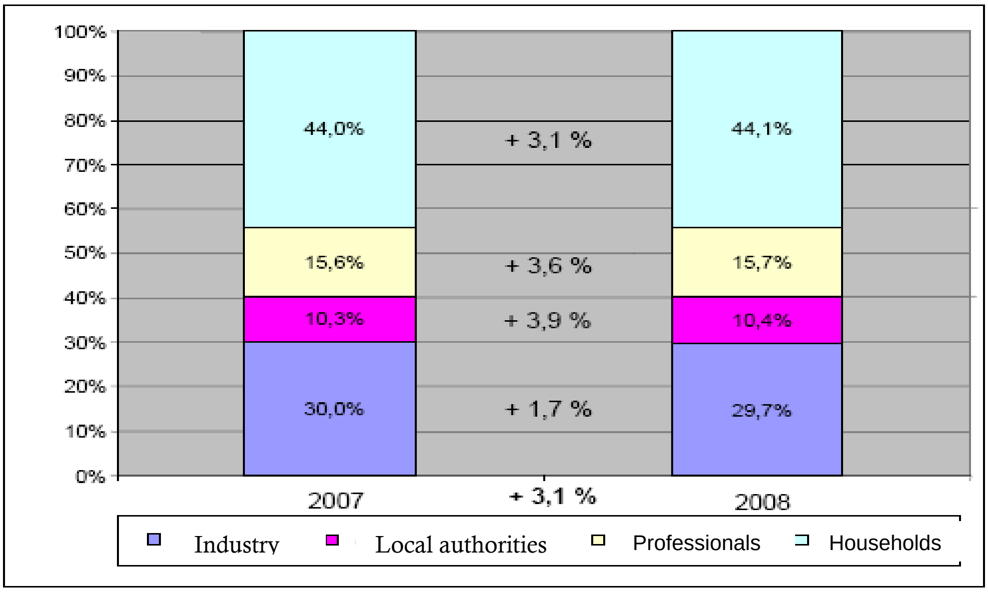
1. The supply-demand balance

1.1 Demand

1.1.1 Energy consumption

The net energy delivered on the grid reached 2,546 GWh in 2008, a rise of 3.4% compared to 2007. This represents the smallest increase rate in 30 years. The maximum peak power consumption of the grid reached 408 MW, a rise of 1% compared to the peak in 2007. It is noteworthy that in 2008, the total leakage of the network reached 228 GWh that is 9% of the energy delivered. This is mainly attributable to technical leakage, but also to “economic” losses (network fraud).

Figure 7 Distribution of electricity consumption between different types of customers



Source: EDF Réunion (2009)

1.1.2 Electricity demand management (EDM)

For several years, the members of the energy management committee in Réunion and of the regional programme for energy management (featuring the region, the State, the ADEME and EDF) have continued to conduct a very active policy in terms of EDM supply, based on activities in the field, financial incentives and the promotion of certain products. In 2008, according to EDF Réunion, interventions concentrated upon:

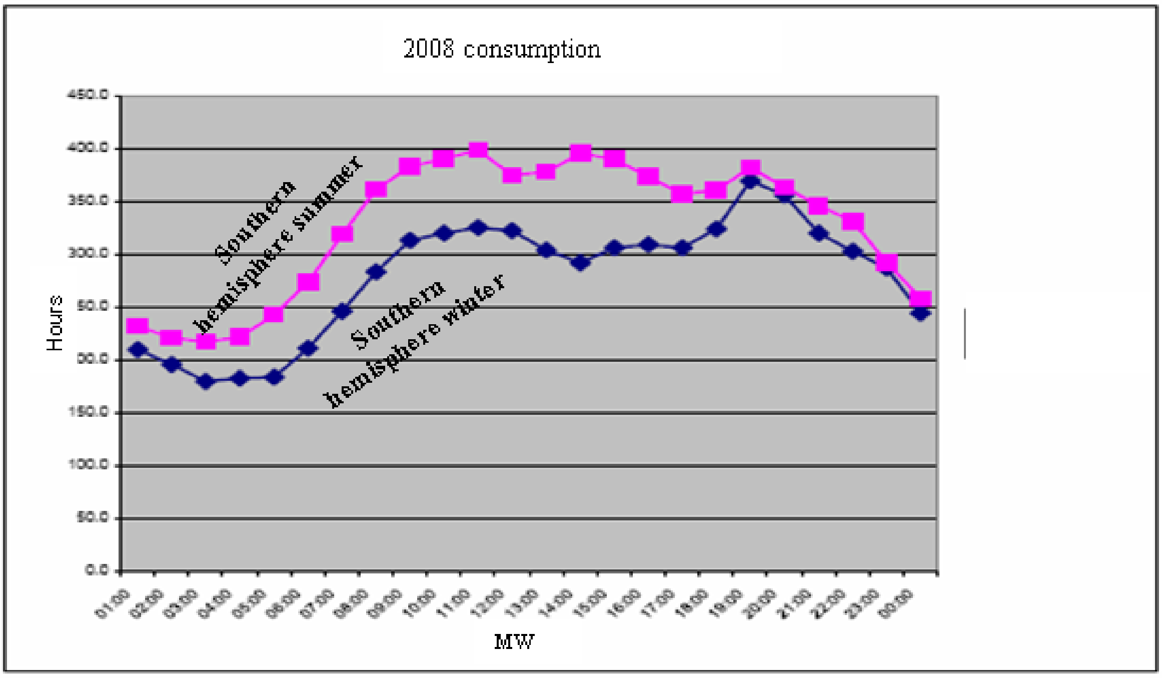
- Large-scale retailing of low energy light bulbs (548,000 units);
- Installing 10,000 solar water heaters;
- Promoting low-peak and high-peak energy tariffs;
- Optimising a number of industrial processes.

This represents a total of almost 22 MW shaved off the peak and more than 36 GWh of energy production averted during 2008.

1.1.3 The load curve

In Réunion, the load curve is characterised by a morning peak sensitive to the temperature (mainly tertiary sector air conditioning), and an evening peak affected by household consumption (essentially lighting and household appliances). It is also noteworthy that in the southern hemisphere summer (November – March), in the hot season, the differential between the morning and evening peaks is less perceptible. During the southern hemisphere winter, a more temperate season, the evening peak stays higher than the morning peak. The following graph (see figure 8) illustrates this relatively marked seasonal behaviour.

Figure 8 Progression of the load curve during the southern hemisphere winter and summer

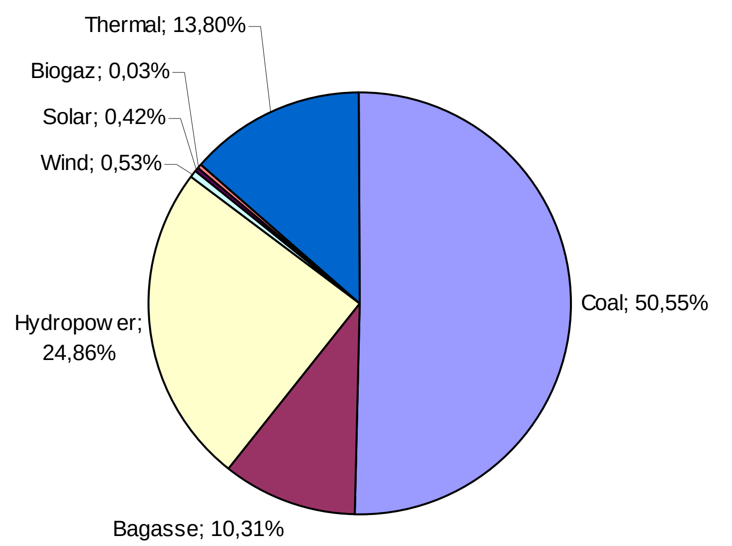


Source: EDF Réunion (2009)

1.2 Electricity supply

The island's electricity supply comprises a diverse combination of energy sources. The share pertaining to RE reached 36% in 2008 thanks to the hydro-electric power station and to the use of bagasse for energy (see the figure 9 which illustrates the structure of electricity production).

Figure 9 : Combination of energy sources en 2008



Source: EDF Réunion (2009)

1.2.1 Thermal means of production

a. Off-peak production means

– <u>The Port power plant</u>

The Port power plant comprises 10 diesel engines working on an off-peak/mid-peak load, for a total installed capacity of about 125 MW.

– <u>The Bois-Rouge power plant</u>

The Bois-Rouge bagasse-coal power station comprises three divisions for a total capacity of 100 MW. The two first divisions, in use since 1992, run on bagasse during the sugar season from July to December and on coal for the rest of the year. The capacity released diminishes during the sugar season due to the sugar factories' consumption of steam. The third division, with a capacity of 45 MW, was put in use in late 2004 and runs on coal all year. If necessary, this division can also run on bagasse.

– <u>The Gol power plant</u>

Working on the same basis as the Bois-Rouge power plant, the Gol power plant comprises two coal-bagasse divisions in service since 1996, and a new 52.5 MW division put into service in late 2006 which runs on coal. The total output outside the sugar season reaches 111.5 MW.

b. Peak production means

Peak production means are distributed across two sites: three 20 MW combustion turbines (CTs) at the Port power plant and two 40 MW CTs at the La Baie power plant (within the Port commune). Both 40 MW CTs are equipped with a denitrification system.

1.2.2 Renewable energy sources (RES)

a. The hydropower infrastructure

Réunion has six major hydro-electric stations: Langevin (3.6 MW), Takamaka 1 (17.4 MW), Takamaka 2 (26 MW), Bras de la Plaine (4.6 MW), Rivière de l'Est (66 MW), Les Orgues (1.2 MW) and Bras des Laines (2.2 MW), for a combined power of 121 MW. Their operation, although essential for the electricity system, is limited by the size of water reserves equivalent to a few hours of full-power turbine performance. The energy is distributed over the day as well as is possible by alternating the storage and release phases. Smaller stations operate as run-of-river power stations. According to EDF Réunion, the average power generated by Réunion's hydro-electric stations is around 60 MW. The highest possible power generation would be around 121 MW.

b. The wind power infrastructure

There are two wind farms on the island: the Sainte Rose farm (6.3 MW), which was put into use in 2004, and the La Perrière farm (4.0 MW) which was initiated in 2006. The contracted installed capacity should increase to 14 MW in total in 2009 as a result of the reinforcement of the network.

c. Grid connected photovoltaic power

At the end of 2008, there were approximately 10.68 MW of grid-connected solar panels in Réunion of which 6.4 MW were high voltage ac input and 3.6 MW were low voltage.

d. Biomass

The Gol and Bois-Rouge power stations which run on bagasse and coal produced 270 GWh (i.e. 34 MW) from bagasse in 2008.

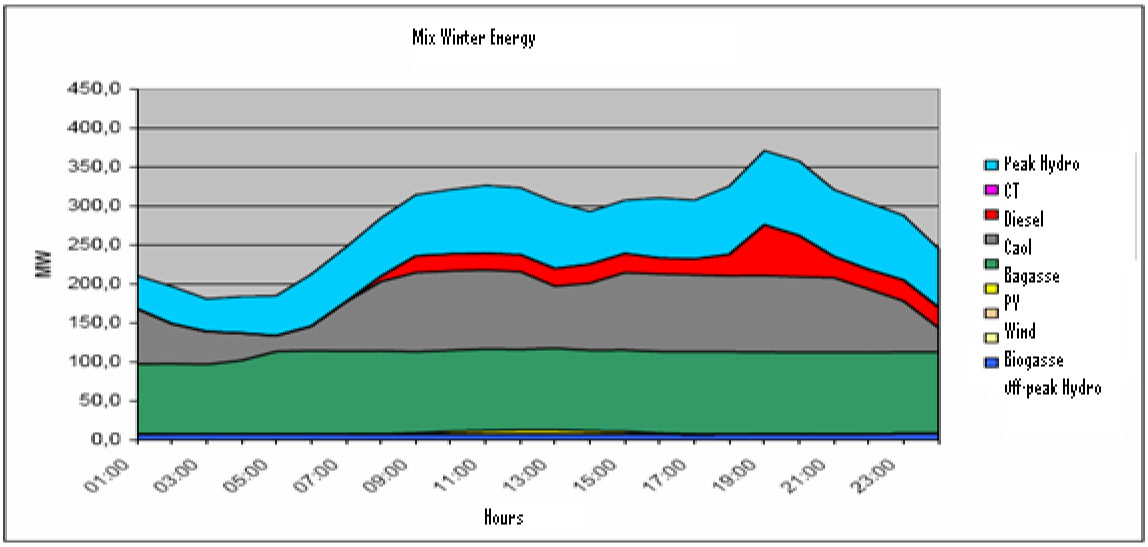
e. Biogas

A 2 MW unit which makes use of biogas from the Rivière Saint Etienne sub-surface solid wastes landfill site has been in use since the end of 2008.

1.3 The balance of the system

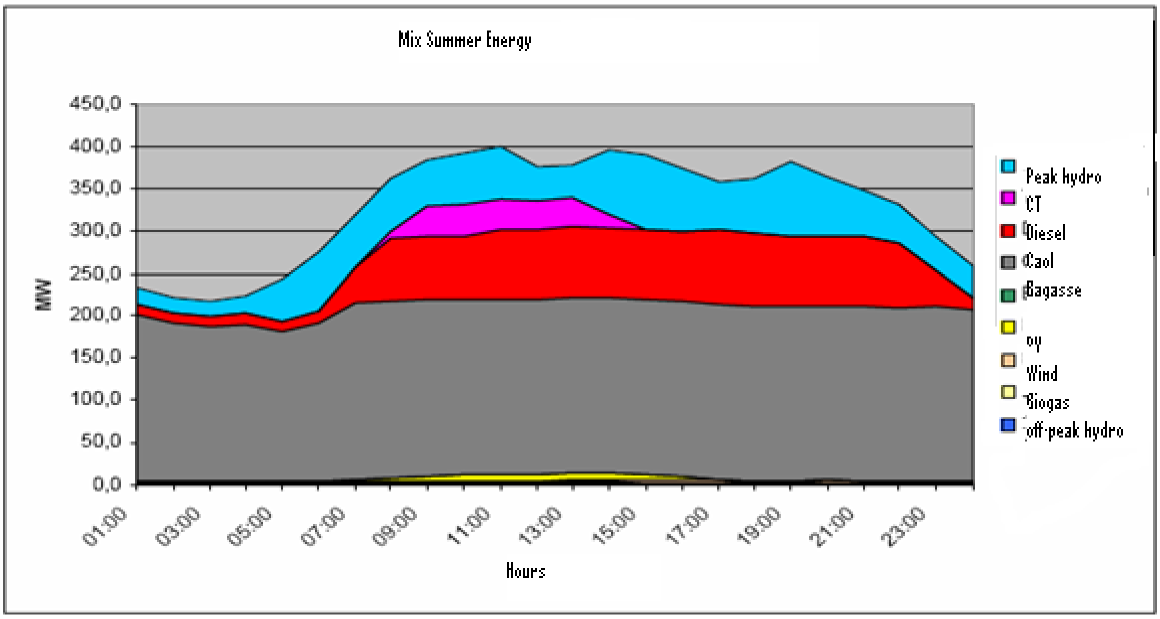
The graphs below (figures 10 and 11) illustrate the stacking of production means available for two days, one during the southern hemisphere winter (July) and the other during the southern hemisphere summer (December). According to EDF Réunion, production means are put into use according to a "merit order" to guarantee the balance of supply and demand at the lowest cost.

Figure (10): Winter energy mix



Source: EDF Réunion (2009)

Figure (11): Summer energy mix



Source: EDF Réunion (2009)

The run-of-river power station production, purchase obligations and coal production (bagasse during the second semester) constitute off-peak load production. On mid-peak load, the diesel driven generators are used in order to optimise inputs of peak hydro-electric power. Indeed, the infradaily hydro-electric storage capabilities allow its input during both of the peak periods and its storage outside of these times.
Finally, combustion turbines are used mainly to cover shortfalls and ensure the balance of supply and demand during the most overloaded summer days.

IV. Difficulties in market penetration for renewable energy in Réunion

As a tropical island, Réunion constitutes a valuable example to gauge the relevance and the limits of renewable energy development in supplying energy for an insular territory. In many respects, Réunion enjoys particularly favourable conditions for developing renewable energy. What conclusions can we draw today about the remarkable confluence of favourable elements for renewable energy development? Yet at the same time, this island also encapsulates some of the difficulties associated with the voluntarist promotion of these energy sources.

An analysis of the contribution of the different renewable energy sources to electricity production in Réunion shows that, apart from hydropower and biomass, the contribution made by other sources is minor. In 2008, the contribution of renewable energy sources such as PV and wind power barely reached 1% of total production. The launch of the PRERURE has clearly not translated, at least so far, into stopping or even slowing the decreasing trend of the share of renewable energy in the island's electricity production. Between 2000 and 2008, this share retreated from 47% to 36%. In this context, what are the obstacles to large-scale development of renewable energy sources in Réunion? To answer this question, we can put forward two groups of factors: the first is linked to the intrinsic disadvantages of RE; the second relates to problems specific to the environment in Réunion.

a. Disadvantages of renewable energy sources

- RES remain expensive and uncompetitive with respect to present technology, except in the case of hydropower and, at times, biomass. In Réunion, the cost of investing in RES and EDM is high, which impedes their development in tertiary and industrial sectors. Furthermore, the low purchasing power of the Réunion people obstructs the development of RES in the private residential sector as they often elect to favour running costs rather than investment costs.
- Decentralised RES require a high initial investment and this effort constitutes a barrier to entry for many consumers who are not able to advance or borrow the necessary funds, however favourable the projected profits may be over the lifetime of the installation.
- It is difficult to anticipate at present which energy source will benefit most from a decrease in production costs through a "learning curve" effect and economies of scale linked to mass production: Wind power? Photovoltaics? Thermo-solar power? To answer this question, we need to examine the situation on the global markets, but also take into account the idiosyncrasies related to the island's isolation. Furthermore, the structure of the industry must be analysed, as well as the concentration of businesses and the degree of competition within the sector. Many specialists thought that costs would decrease more dramatically in the case of thermo-solar power stations than in that of photovoltaic power stations, but competition is more spirited in the latter than the former, and mass production in China is currently decreasing PV costs faster than those of thermo-solar installations.
- RES implie lower power production and an intermittent supply. The production of some renewable energy depends on the availability and the regular input of its sources. This cannot always be guaranteed in Réunion (as shown by the intensity of rainfall, wind speed and cloud cover for example). Added to this, photovoltaic power is generally low and even insufficient on isolated sites, and so backup energy sources become necessary.
- Local producers' mastery of the technologies is sometimes inadequate, and the numerous counter-productive operations may discourage people from choosing RES.
- Negative impacts on the local environment may result. Implementing certain technologies in a given area can be harmful. For example, they are generally space-consuming by nature, and some, such as wind turbines, are eyesores and a source of noise pollution.

b. Obstacles specific to the local Réunion context

Some local obstacles to the development of renewable energy include (cf. N. Picou and C. Henry, 2001):

- An exceptionally strong and sustained increase in energy and electricity consumption in Réunion. RES cannot alone satisfy the entire rise in demand since it is growing faster than any voluntarist promotion of renewables could do.
- Limited space. Space available for setting up new energy production units, whatever their nature, is limited due to land pressures related to demographic growth on the

one hand, and to the nature of Réunion's terrain on the other, as it comprises zones where access is difficult or entirely impossible.

- Natural and climatic risks, including the risk of cyclones (a significant danger to wind power installations), as well as volcanoes, tsunamis, flooding, etc.
- The population is not always sufficiently informed about certain factors, among these the true status of the island in terms of energy, the technical and economic characteristics of RES and EDM, and the true potential of renewable resources and energy saving.
- The lack of a full consensus between the various agents in Réunion on the need for prioritising renewable energy development on the island.
- Creating projects relating to RES and EDM is difficult for the following reasons:
  - administrative procedures are long and difficult
  - public services and local authorities are greatly lacking in capability and human resources, both for the administrative follow-up of projects and for supporting project leaders
  - the aid schemes put in place by the ADEME, the Réunion Regional Council, EDF and Europe are opaque to project leaders
  - fixed feed-in tariffs are lacking for most RE sources, with only a few benefiting from them
  - environmental legal constraints exist, notably with respect to listed sites, environmental impact assessment, water rights, etc., which penalise RES by extending procedures or by prohibiting certain installations.

c. Problems relating to standardisation of electricity tariffs based on average cost pricing

We can add the geographical standardisation of electricity prices based on average cost pricing in Réunion to the above-mentioned local obstacles preventing large-scale renewable energy development. In consequence, the kWh charge is identical across the nation, a fact which plays against renewable energy as were it not for this provision some sources would be economically competitive in certain cases.

Electricity is considered as a public service and in the act passed in February 2000, the government reiterated that the kWh tariff should be equal for all French citizens, whatever their geographical location. This means in practical terms that a consumer must not be penalised due only to the fact that he lives in an isolated area or in an overseas department. The principle of standardisation based on average cost pricing was thus confirmed, which is not to say, however, that there may be no differentiation of tariffs according to the time of day or the time of year, leading to an hourly or seasonal differentiation of electricity prices. As a result, we have "peak-time" and "off-peak" tariffs, and the price of electricity may vary considerably according to the time the grid is accessed. The principle of equity implies that all consumers in the same situation pay the same price, and conversely that consumers in different situations pay a different price. One kWh produced during peak time when the last power station contributing to the grid is expensive does not constitute an identical product to a kWh produced during the off-peak period when the marginal power station enjoys a low variable cost. Standardisation on a time basis is thus compatible with the principle of equity. Geographical standardisation based on average cost pricing, however, would translate to charging more for a kWh to consumers far from the production location, as distribution costs are higher. Similarly, consumers in the overseas departments and territories of France should pay for their kWh on the basis of local production costs, which are higher than on the mainland since connection to the national grid is impossible. The legislator in all its wisdom decreed that these rural or overseas consumers should not be penalised. The retail price of the kWh is thus much the same on Réunion as in mainland France. On average, a kWh costs considerably more to produce on the island than the local consumer is charged (generally double or quadruple the price), the deficit being covered by a grant financed thanks to the CSPE (contribution to the public service of electricity) which is financed by French consumers as a whole. This can be summed up as a cross-subsidy between mainland and overseas consumers. The transfer is estimated at about 150 million euros; that is around 500 euros per year and per EDF consumer on the island, which comes to about 5 euros per French electricity consumer. This apparently justifiable system can nonetheless have negative effects since it incites electricity producers to invest in fuel or coal power stations whereas logic of "cost-reflective pricing" should lead to their choosing solar or wind power plants. Subsidising wind or solar energy is therefore justified (by logic of guaranteed feed-in tariffs) since in any case the consumer does not pay the true price of the fuel or coal kWh.

In sum, it can be said that, taking into account the intrinsic characteristics of renewable energy and the geographical, climatic and human conditions of Réunion, it is difficult to gamble on a 100% renewable solution. At most, we can hope for a greater contribution from renewable energy in Réunion's energy system since, for some uses, particularly industrial, and in certain cases such as large conurbations, power needs can be only inadequately served by wind or photovoltaic power stations. Standard thermal power stations could not be replaced by wind farm or solar panels whose power and constancy are lacking. In the sphere of thermal solar power, individual solar water heaters are usually coupled to an electrical backup and thus allow the user to save energy. This is also the case of photovoltaic installations. In the absolute, the intention is not for renewable energy sources to replace standard energy sources, but to complement them in order to balance Réunion's energy balance.

The goal of energy self-sufficiency for the island is ambitious but presupposes that technological progress be made in managing intermittent supply or replacing imported fossil fuels. As for producing electricity, it is likely that it will remain, at least in part, dependent on imported products (notably coal).

V. Negative effects of renewables on the electricity markets

The keen interest for renewables tends to be waning in many European countries due to problems raised by systematic recourse to systems of over-expensive feed-in tariffs. These lucrative prices, intended to compensate for the extra cost of renewables, are generally paid for by the consumer population as a whole, and sometimes by the taxpayer, which contributes to the rise in electricity prices for the end user. In France today, subsidies for renewables account for two-thirds of the CSPE. In Germany, nearly a third of the price paid by the domestic electricity consumer corresponds to financial relief for renewables. However, some cases are still more paradoxical. In Denmark, as in Germany, wind power is sometimes responsible for negative prices on the electricity spot market. When demand for electricity is low, for instance overnight, and when winds are high, the off-shore wind turbines, which are prioritised on the grid and whose feed-in tariff is high, are responsible for an excessive electricity supply to the network. Electricity cannot be stored, so the inflow must constantly be equal to the withdrawal rate. Some thermal power stations should therefore be shut down to let the wind-powered electricity through, but it is often less expensive to pay an operator to acquire this excess of electricity than to stop and restart a thermal power plant two or three hours later. As a result, some “buyers” are paid to acquire this electricity. These include for example Swiss operators who have pumping capabilities: they use this electricity to pump water into mountain reservoirs and they use this water to produce electricity during peak periods via pumping power stations. They are paid to acquire electricity during off-peak periods and this allows them later to produce electricity when its price is very high on the market during peak hours, so they win on both levels (cf. J.P. Hansen and J. Percebois, 2010). This negative side effect could well compromise the enthusiasm felt for certain forms of renewable energy. An alternative solution could be to pay wind farm owners to agree not to inject their electricity onto the grid, but this would also be expensive. This explains the fact that in 2009 there were 23 cases of negative prices on the German electricity stock-market. The same phenomenon occurred in Denmark in 2008 and 2009. Certain financial incentives are therefore unjustified and generate excessive costs for the community. This does not, even so, throw doubt upon the promotion of renewable energy, but a full costs-benefits analysis must be conducted in order to justify the aid granted.

VI. Tools for promoting energy savings and renewable energy

The will to promote renewable energy with a view to energy self-sufficiency begs the question of knowing which measures should be favoured by the authorities. Should the feed-in tariff system be furthered, as is currently the case for wind and photovoltaic power, or should a tender procedure be instituted, perhaps even with a method of “green certificates” as is the case in other European countries? The tender system has not shown very good results (see the relative failure of the EOLE Plan in France). The green certificate system exists in England and appears to work fairly well. The principle is as follows: electricity suppliers are obliged to sell a minimum proportion of green electricity. They can either produce it themselves or buy certificates from operators who have produced green electricity without being obliged to but who in exchange for their production have received a certificate attesting that they have indeed produced it. This theoretically incites the most efficient operators to produce green electricity. The system of feed-in tariffs, used in several European countries including France, Spain and Germany, also seems to have produced good results, and it is without doubt more efficient than a tender system. However, the three systems can be used simultaneously: the French government has, for instance, used invitation to tender as a complementary solution to certain off-shore green electricity projects for the mainland.

In the road transport sector the issue is more sensitive. Can the use of the car be reduced if replacement policies (public transport) are not available? Must emphasis be placed on technological progress aiming to reduce fuel use per vehicle, or should we opt for a system of urban tolls as is the case in Singapore, London, Oslo or Stockholm?

In the domestic and tertiary sectors, the system of “white certificates” (energy savings certificates) currently in existence in France seems promising because a significant potential for various kinds of savings emerged during the first phase of the operation. Energy suppliers are obliged to make savings in the home and they can incite their clients to fulfil them. The savings achieved are exchanged for certificates which are negotiable on a market. The goals have been surpassed, although it is true that they were not very restrictive as the operation was experimental. Furthermore, a significant “windfall” effect seems to have been noted. The goals will be perceptibly more restrictive in the second period which begins in 2011. Naturally, energy savings programmes, particularly as concerns electricity, must be a priority in a region where every kWh produced is sold at a loss or at a price which does not cover all of the social costs. For the rest, a combination of several categories of measures will doubtless be necessary, to be adapted according to patterns of behaviour and their evolution.

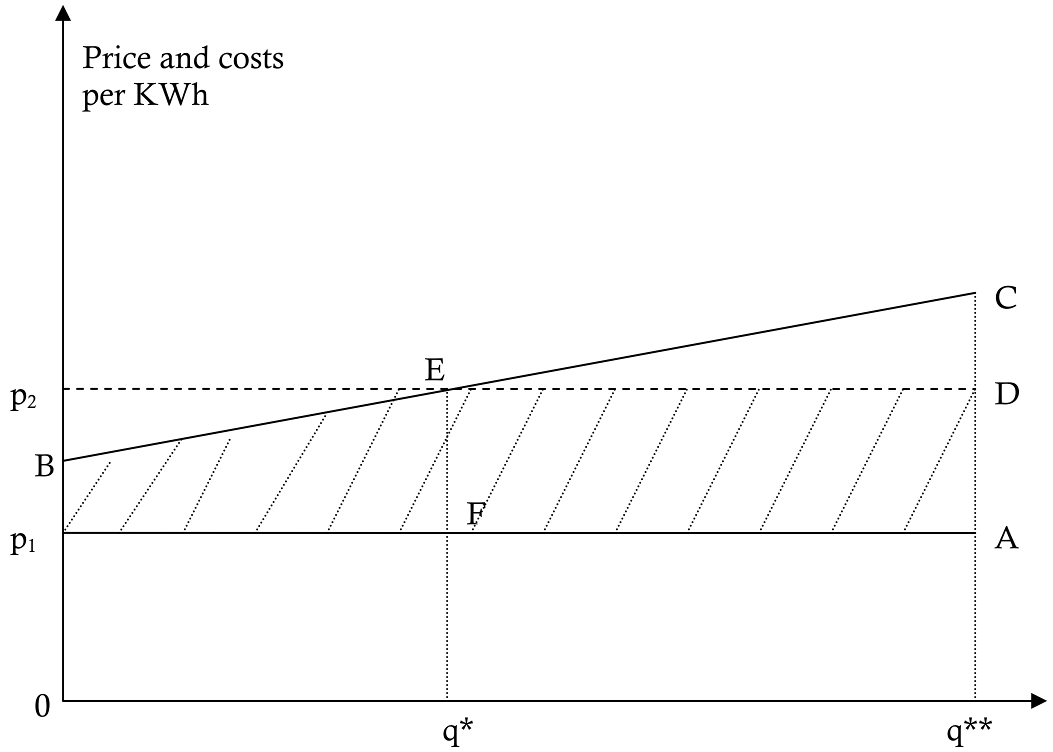
The debate is also revived on the question whether, in response to pollution and global warming, it is best to fall back on taxation or on a carbon credits market. The system currently in use by the European Union is a system of carbon credits which can be traded on the market. Every European country requests the allocation of a quota of carbon credits from Brussels (National Allocation Plan) which are then distributed between the principal polluters. These polluters can sell unused credits on a market and must acquire them on this market if their pollution exceeds the quota attributed to them. This motivates operators to be efficient since they earn money if they do not use all of their carbon credits, and lose money when they need to buy. The problem today is that the attribution of quotas has been relatively lax in the context of slow economic growth, so that the price of a tonne of CO_2 has fallen (less than 2 euros during 2007 as opposed to nearly 30 euros in 2006 and 15 euros in late 2010). This suggests the necessity of reinforcing this system by establishing an additional tax. There is already a general tax on polluting emissions (the TGAP) in France, but some believe that a specific tax on carbon emissions would add force to the fight against global warming.

The various aid packages dedicated to renewables must also be analysed in the more macroeconomic aspect of the effect they have on employment, the industrial base, exports, and technology transfer. Only an LCA-type analysis (life-cycle assessment) can inform us about these macroeconomic effects. We must scrutinise the constituent elements of each energy system and consider what is locally produced, what is imported, what creates jobs. We must also analyse the structure of the industrial sector that manufactures these various elements to see whether competition is strong or not, whether economic rent strategies explain prices, and whether any technological progress may be predicted and if so in what time frame.

Resorting to the feed-in tariff system is a justifiable option, but its disadvantages or negative effects should not be underestimated. The diagram below shows that feed-in tariffs for wind-generated electricity can collectively be beneficial in a country or an area where the price of standard or traditional electricity does not cover costs. Supposing that the retail price of a kWh is fixed at the p1 level (the uniform price across the whole French territory by virtue of respect for geographical tariff standardisation) and that the consumption of kWh taken into consideration is equal to Oq**. At this price, EDF suffers a loss on the island of Réunion since the marginal cost of electricity production is posited constantly above the retail price as shown by the line BC. The total loss is equal to the surface area of p1BCA. We assume that the marginal cost is increasing; the first power stations were hydro-electric power plants and the following were thermal power stations using expensive imported fuel. We suggest that this marginal cost includes external costs such as environmental costs and the purchase of carbon credits.

Let us suppose that the authorities establish a feed-in tariff equal to p2 for the Oq** wind-generated electricity produced (see figure 12) Initially, the wind-generated kWh feed-in tariff is greater than the marginal cost of standard electricity production; this is the case until the level Oq*. This price can, however, drop below the marginal cost of thermal electricity, especially if the externalities are taken into account (environmental costs, purchase of carbon credits, the cost of dependence on imported energy, etc.). From the point q* the feed-in tariff is lower than the marginal cost of thermal energy. Between q* and q**, resorting to wind-generated electricity leads to an “avoided cost” equal to the surface area of EDC. The additional cost borne by EDF when wind-generated power is substituted for standard electricity (for a sum equal to Oq**) is therefore equal to the surface area of p1p2DA. This additional cost may be lower than it was initially if the surface area of Bp2E is less than the surface area of EDC, i.e. if the additional cost of the wind-generated electricity compared to the production cost for the quantity Oq* is less than the “avoided cost” for the quantity q*q**.

Figure 12 Economic competitiveness of RES with a fed-in tariffs system



This analysis can be extended by taking into account positive externalities linked to producing wind-generated electricity. This can be done by allowing for the effects on local employment and on the activity of local industry. However, deduction must be made of the macroeconomic effects linked to the fact that imported electricity also generates employment and local benefits. Only a blow-by-blow impact assessment, using the “effects method”, a regionalised input-output table or an LCA approach would resolve this question. The main thing is to understand that feed-in tariffs are not necessarily synonymous with losses but that they are not systematically synonymous of social benefits either.

VII. Conclusion

For an insular territory devoid of fossil energy resources such as Réunion, the development of renewable energy puts vital economic, social, financial and environmental factors at stake. Indeed, promoting renewable energy can aim to achieve several goals at once:

- Reducing the island’s energy dependence on fossil energy imports whose price is constantly increasing;
- Lowering energy expenses;
- Diversifying energy supplies and ensuring supply security;
- Preserving a tropical environment which is fragile but crucial to the tourism sector;
- Limiting damage to the environment and ensuring sustainable development;
- Relying on a largely inexhaustible local energy resource.

Currently, Réunion is a national pioneer in terms of thermal and solar energy development. It also has a considerable head start with respect to the objectives set by the European Union in terms of the contribution of renewable energy sources to the energy and electricity overall account.
However, renewable energy is not a panacea, for at the current stage of existing technology, it is expensive and uncompetitive, and it presents a certain number of flaws: its supply is often intermittent, irregular and insufficiently powerful.
As a consequence, renewable energy development cannot alone offer a global, inexpensive and immediately applicable solution to the current energy problems encountered on the island. Renewable energy will probably not suffice to ensure the self-sufficiency of electricity production as desired by the Réunion Regional Council if considerable energy savings are not made and if the rate of increase of energy consumption does not slow significantly.
Nevertheless, local authorities must continue to intervene and support en masse the development of renewable energy. This is the only way to slow the pace of carbon emissions and reduce the island's energy dependence.

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