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Analysis of potential for market penetration of renewable energy technologies in peripheral islands

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Abstract

Cape Verde Islands have important energy and water problems that limit their social and economic development. A field study will be performed focused on Cape Verde Islands to describe the present and future regional power market and to give a clear indication of the best strategies for the optimization of the power energy supply mix in Cape Verde Islands. The study will take into consideration renewable energy technologies and the concerned social, economic and environmental aspects of a given set of possible strategies. One case study will be considered in detail: the situation of the Santo Antão Island. Different energy technologies will be considered: solar, wind, geothermal and biomass. The present structure of the energy sector (capacity, distribution); energy demand, supply and trend; generating plants and infrastructures of Santo Antão will be described. © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: Cape Verde; Insular region; Energy self-sufficiency; Renewable energy; Sustainable development; Energy managment

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1. Introduction

A significant portion of the about 140 developing countries in the world are islands that have a population of less than 5 million and a very small gross national product (GNP). These countries have a special set of economic, political, geographic and environmental characteristics that set them apart from the larger developing countries. Insular and remote regions present some specific problems related to energy supply due to their isolation, the lack of conventional energy sources and small dimension of the energy market [1].

Almost all small islands and some remote regions have substantial renewable energy resources, which are not developed yet to their full potential. As indigenous resources, the use of renewable energy resources can enable local development, contributing to reduce the dependence on energy imports, to minimize CO_2 emissions, to create jobs and to improve living standard. This is particularly outlined in the European Union White Papers for a Community Strategy and Action Plan [2], which attest the high interest in this approach. The objective 100% power supply from renewable resources is also highlighted as one of the main key action to promote renewable energy [2].

Small island developing states (SIDS) have special energy problems aggravated by a lack of land resources. Resource management schemes applied in other countries can therefore only have little impact in these countries. Renewable sources of energy such as solar, wind, biomass and wave power offer some hope in the long term, especially if islands work together to develop technologies that are tailored to their unique requirements.

In many cases, renewable resources are used for the production of energy for different purposes. The American Island State of Hawaii shares with many other isolated regions the problem of identifying a secure and affordable supply of energy. Sufficient progress has been made to date in commercializing a number of alternative energy sources that prove that Hawaii will be able to achieve energy self-sufficiency with its indigenous renewable resources [3].

The Cyclades is a complex of 32 small islands in the Southwest Aegean Sea. Lack of energy resources and high transportation cost are the major constraints in economic development of the islands. However, the islands have a wealth of renewable and non-conventional sources namely solar, wind and geothermal energy. The economic compatibility of the soft energy sources for a variety of technologies and end-uses were demonstrated by using an energy optimization model to determine optimal allocation of these sources [4].

Cape Verde, as one of the smallest and poorest SIDS, has additional constraints resulting in poor alternatives. Fuel costs are of the order of twice the world market price. The shortage of water resources leads to the use of desalination plants, which are heavy energetic consumers. The country has wind energy resources from the trade winds providing a strong northeasterly flow for most of the year. Wind turbine technology enables extraction of energy from the wind for conversion into electricity. Since the early 1980s many experiments have documented the technical and economic feasibility of today's wind energy

technology of Cape Verde. A significant fraction of the electricity consumed is now produced from the wind. Modeling has shown that further expansion of the use of these technologies is possible and economically attractive for Cape Verde [5].

For social reasons, the price for petroleum products, subsidized by the government, is the same for all the islands even though the cost is greater for the less developed islands, which include Santo Antão. This island is one the poorest but one of greenest islands of archipelago of Cape Verde. The magnificent mountains across the island are the main natural resource but they are also the reason for its present poor development. Santo Antão has all the characteristics of an insular region aggravated by the constraints related to mountainous regions. Therefore S. Antão constitutes an excellent case study and the obtained results will be helpful for both insular and mountainous regions.

The achievement of this study will also provide useful information to allow public and private decision-makers a better decision choice in technology for power generation for the Cape Verde Islands and others peripheral islands or archipelagos with similar power systems size and characteristics.

2. Geography and climate

Cape Verde is an archipelago of 10 islands and several islets of volcanic origin lie around 600 km off the coast of West Africa in the Atlantic Ocean. The overall land area is of 4033 km^2. Nine of the ten islands are inhabited and the population is around 370,000. Over half of the population lives on the largest island of Santiago where Praia, the capital, is located. The highest point of the country is situated at the island of Fogo, an active volcano (Pico do Fogo, last erupted in 1996) that reaches about 2800 m. Santo Antão is the second biggest island (779 km^2) characterized by mountainous landscape, with hills reaching 1979 m (Topo da Coroa). The population is around 44,000 people, living mostly from agriculture and fishing activities.

Cape Verde natural resources are fish, salt, pozzolana, and limestone and the agriculture products: bananas, corn, beans, sugarcane, coffee, fruits, and vegetables. There are some industries such as fish and fish products, salt, construction, building materials, ship repair, clothing, shoes, furniture, metal products, beverages. Tourism sector remains the most promising for further development. Santo Antão has recently developed green tourism demanded mainly from Germany.

There are 1100 km of roads in Cape Verde, of which 680 km are paved. The density of the road network is about 27 km^2 per inhabitant. For Santo Antão the high mountains make it difficult for direct access from one point to another and building roads is very slow and expensive, but all the main counties are joined by road.

Due to its geographic location, in the arid region of Sahel (an arabic word meaning the *doors of the desert*), the climate of Cape Verde is tropical and arid. There are two seasons: a long dry season from November to June and a short and

irregular rainy season from July to October. Rainfall depends on the annual migration of the Inter Tropical Front (ITF). The ITF is the result of the meeting of two different air masses: dry trade-wind from the north and humid monsoon from the south. Due to the proximity of the high pressure cell of the Azores that blocks the progression of the ITF to the north, the islands are rarely at the south of the ITF, causing the scarcity and the irregularity of rainfall both in time and in space. However, the orography, sometimes important and chaotic, is a factor that considerably increases rainfall, resulting in a variety of microclimates.

Temperatures are moderate, due to the small size of the islands and the regulatory effects of the ocean. The annual average temperature is 24°C. Rainfall on the islands is erratic and occasionally quite heavy. Agriculture is possible in the valleys where rainwater is trapped. Underground water resources are available on many islands mainly in Santo Antão, but their potential and use are limited by the complex volcanic geology of the archipelago. To date, only 32% of the country water resources have been explored. For some islands (Sal, S. Vicente, Praia and Boa Vista) additional installation of desalinisation plants is needed to supply fresh water.

Air humidity is always high, except during some dry periods when the archipelago is influenced by dry and warm winds (Harmattan) that carry great quantities of dust, causing what is known as a dry haze. Insolation is also high in most parts of the country, providing an important potential source of energy.

Rainfall presents a year-to-year variation, not only in space but also in quantity. There are consecutive years with small rainfall causing drought that has led to many deaths in the past. Generally, on the mountainous islands the amount of rainfall is higher; there is a decrease in the total rainfall from the south to the north of the country. The intensity of rainfall is usually high, causing floods and strong soil erosion. As a consequence, the groundwater recharge is poor and over-exploited. This explains the shortage of water all over the country. Thus, the water supply for both the rural and urban population is insufficient with negative consequences. In the urban areas this problem is so acute that the sole solution is seawater desalinisation. The use of runoff water is not common, although there are presently some studies underway for the construction of small dams on the islands, such as Santiago, where rainfall is more important.

3. The structure of the energy sector

The energy sector in Cape Verde Islands is characterised by a high dependency on imported oil products. In 1996, the import of oil products covered more than 70% of all available energy sources. A great amount of the imported fuel is re-exported to supply marine and air transportation. Another source of energy for Cape Verde is vegetation biomass, particularly in the rural areas. Biomass represents 37.4% of the total consumption of energy and is generally used to cook. The use of wood charcoal transformed from larger plant material is included in the consumption of biomass. Kerosene is also largely used for cooking in rural areas while butane gas is preferred in urban agglomerations [6].

A recent project EU-CILSS (Permanent Inter-State Committee Against Drought in the Sahel) to promote the substitution of firewood for butane gas has had a relatively success namely in semi-rural counties. Though this policy is efficient because it decreases the degradation of the vegetation and consequent desertification, it presents some inconveniences in the way the fuel is generally used, generating pollutants and particles that causes health problems particularly in places where the ventilation is deficient.

Wind energy has been used for a long time for pumping water. The manufacturing of wind-pumps is a traditional practice in Cape Verde, especially in Sao Vicente. Recently, promising results have been achieved with the use of diverse types of wind-pumps with different power levels [5]. Solar energy is still at a very experimental phase and is not highly promoted since equipment, such as photovoltaic cells, is still very expensive.

Cape Verde has to take the necessary steps to reduce its dependency on imported sources of energy. It also needs to promote the adequate and safe use of other sources of energy, particularly those that generate less pollution and are less harmful to human health. Furthermore, the cost of such energy must be low, being accessible and affordable for the population in general.

The imported petroleum products for energy are mainly used to generate electricity and for transport. The electricity sector is quite decentralized even though the National Supplier Company ELECTRA controls the production and distribution in the main population centers. In the rural areas the situation is complex. Of 40 electric grids in the entire country, some with an available capacity less than 100 KVA, only four belong to ELECTRA, and the different municipalities administer the other ones.

Globally, only 43% of the population have access to the electric network, and in the rural areas this number does not exceed 14% while the population (372,000 in 1996) is evenly distributed for rural and urban sectors. For Santo Antão Island the numbers are respectively 29 and 19%. It has been found that almost 11% of the families (12% in Santo Antão) will be durably excluded from the conventional power system [6].

The domestic sector is the main consumer (principally for cooking, 50–60%) followed by transport. Between 1990 and 1996 the commercial sector increased about 30% per year (compared to 14% for the domestic sector). Each family spends only about 5% of their total expenditure on energy. Eighty percent of rural families use wood for cooking while in urban areas, butane gas is predominant (80%). For rural families, water supply, roads, health and job are the top of priorities far above electrification. Light, radio and phone are the main reasons for wanting electrification. Refrigerators and TV come next [7].

4. Renewable energy technologies in Cape Verde islands

Renewable energy sources have always been used in Cape Verde Islands. Adapted American windmills for water pumping have been frequently used,

namely in S. Vicente Island. Nowadays the Islands exploits wind and solar energy to produce electricity and for water heating. Since 1994, when wind farms with a total capacity of 2.4 MW were installed, wind energy represents 10–15 % of all the electricity produced. A project to increase in the short term the total capacity to 3.6 MW (at least 25% wind penetration) is waiting for financing. It is emphasized that the extremely high monthly capacity factors achieved in Mindelo (55.6% for the three years 1995, 96, 97 with 59.2% in the best year, 97, and 81.6% in May 97) are surely among the highest in the world for a wind farm of standard wind turbine (three Nordtank 300 kW) [8]. This is important because S. Vicente is the nearest island from Santo Antão and especially from Porto Novo, the poorest county in Santo Antão. As the two regions have similar geo-climatic environment, this means that wind energy can be extensively exploited in Porto Novo.

Solar energy has been used for seawater distillation in the salt mine in Sal Island. Recently solar water heaters have been introduced in Cape Verde with relative success. Within an EU-CILSS project, some schools and private houses were illuminated with photovoltaic modules. Integrated in this project, Maio Island is now almost entirely supplied from waters pumping with solar pumps at the same time solving water supply shortage problems.

Biomass and geothermals have not been yet adequately studied but Santo Antão has some characteristics that point to a great geothermal potential. Some underground reservoirs contain water at temperatures above 50°C. The inhabitants currently use wood for cooking, but a more efficient combustion process and new types of energy must be introduced in order to preserve the scarce vegetation.

The analysis of the success of the new and renewable energy technologies experienced in Cape Verde Island will allow us to choose the adequate technologies to be introduced. Energy and environment policies should maximize the use of alternative sources of energy by giving incentives to the use of appropriated technology [9].

5. Conclusions

In this work, attention has been drawn to the high potential of the renewable sources of energy for small islands developing states, such as Cape Verde. The use of renewable energies facilitates and enables economic activities in agriculture and tourism. Concern over environmental ravage related to energy use has been implied in this paper. For a region with such a hard environment and scarce vegetation, preservation has a real meaning. It is also important to note that renewable energy can have social and economic benefits. For island and remote regions, renewable energy can compete with conventional energies. The study aims to deliver a clear indication of how energy policies can be implemented in order to increase the global contribution of renewable energies in the world energy supply

with beneficial effects—among others in terms of CO_2 emissions, security of supply and employment.

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