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1. INTRODUCTION

Portuguese energy system is highly dependent on imported fuel; in fact, with the exception of firewood, hydraulic energy and a small portion of coal, representing, altogether about 15-16% of primary energy consumption, all the sources are imported.

This situation determines, as incontroversial purposes of energy policy, the reduction of imported oil and the exploitation of indigenous resources; So the definition of an energy policy is not independent from the analysis of the possible contribution of renewable energy resources for the energy supply system, implying an approach based on the following items:

(a) identification of renewable resources and technologies allowing for its conversion in energy forms of direct consumption (useful energy); characterization of the state of the art of the technologies (state of commercialization, fundamental or applied research) and cost of energy produced; evaluation of available energy in the country under useful forms as a function of the resource and of the conversion technology;

(b) investigation of the interaction between the available renewable energy and consumption structure;

(c) examination of barriers raising difficulties to the implementation of renewable resources conversion technologies and identification of political actions, at national and international levels, favourable to a larger contribution, when justifiable, from renewable energy to the energy supply system.

It should be noted that, although not explicitly refered in this document, energy conservation technologies can be considered, under the point of view of its effect, as equivalent to the renewable energy conversion technologies; both groups of technologies allowing conventional, imported in the portuguese case, energy resources economies.

2. RENEWABLE RESOURCES, CONVERSION TECHNOLOGIES, COST OF ENERGY PRODUCED, USEFUL ENERGY AVAILABILITY

2.1. *SOLAR ENERGY*

Solar radiation energy potential in Portugal varies between 5400 MJ/m^2year and 6800 MJ/m^2year.

2.1.1. *Conversion of solar energy into low temperature heat*

The most employed technology is the flat plate collector (air or transfer liquid). Passive forms and solar ponds are other envisaged solutions.

Flat plate collectors are already made and commercialized in Portugal and they are mostly applied as domestic water heaters. There are projects on this kind of technology under way namely: demonstration and development projects of pool heating, crop drying, greenhouse heating and solar refrigeration (1) a fundamental research project on sellective black cromium coating (2), a solar house (3), and the project of a solar pond for greenhouse heating was recently finished. The annual amount of available energy from flat plate collectors would be 2.7 to 3.4 GJ/m^2 for North and South parts of the country, respectively.

The cost estimates for this low temperature heat (given a 50% coeficient of performance) are: $200-750/tep using flat plate collectors; $70/tep for solar ponds (not regarding the transport of the salt which price depends on the site of the pond) and $40/tep for the energy collected by passive forms.

2.1.2. *Conversion of solar energy into medium and high temperature heat*

The technologies for these conversions are not commercialized in Portugal although the manufacturing and commercialization of non-focusing concentrators is foreseeable. Meanwhile, the conversion of solar energy into medium and high temperature heat has been the aim of the following research and demonstration projects: testing of CPC prototypes (4) without vacuum tube and with a convective barrier; one prototype with a vacuum tube and one external mirror will be soonly tested connected to the high temperature test circuit on project (5). The same type of collectors (CPC's with vacuum tubes) are the object of a project for their future commercialization (4).

Two demonstration projects for industrial steam generation based, one on CPC collectors, the other on parabolic cylindrical mirrors are running on for application in cork industry and milk processing plants, respectively. This late mentioned project is the result of a cooperation project between the Governments of Federal Republic of Germany and Portugal, involving the share of tasks by a german manufacturer of concentrators(6), a portuguese engineering firm (7) and one portuguese research institute that will conduct the test and measurements program (1).

The costs of produced energy is, of course, variable with envisaged technology. The available figure for the produced energy cost in these projects (\$0.17-0.25 /kWh) is not meaningful, because about one third of this cost is the plant's instrumentation and testing, and it's also expectable that resulting from commercialization and development of these technologies there will be a decreasing tendency on costs; considering all this, in a medium term period (about ten years) the cost will fall in the range of \$0.02-0.1 / kWh. Available thermal energy at these temperatures, despite the performance coeficient variation with the geometry, rate of concentration and specific aspects of the systems, can be evaluated in the same range as for low temperature heat.

Electric energy production from a thermodynamic cycle based on solar energy is not, at the moment, the object of research or demonstration projects in Portugal. The cost, considering the development state of this technology, would be three times higher than the thermal energy directly obtained by concentration of solar radiation.

2.1.3. *Direct conversion of solar energy into electric power*

Photovoltaic conversion is the technology used. Imported single crystal silicon solar cells are already commercially available in our country.

Applied research on this subject and manufacturing of amorphous silicon cells and cadmium sulfide cells (CdS/Cu_2S) has been done in Portugal (8). Now works are going on about encapsulation. Manufacturing single crystal solar cells is also posssible (8).

A program to optimize the design and tilt of modules of stand alone photovoltaic systems for remote applications has been developed (9); measurement and control equipment for these systems is available (9). A demonstration project of a solar cell power system for remote applications is now in progress (10).

Estimating an 82% efficiency for this type of systems we can reach an amount of useful energy in our country between 120-150 kWh/m^2 year. Costs are estimated to be in the range of \$0.9-\$2.7/kWh.

Photogalvanic and photoelectrochemical conversions are also other possible processes. On these subjects we should refer:

. a research project on the examination of the electrode kinetics, on modified electrodes of a photogalvanic cell based upon the photoreduction of thiazine dyes by organic redox couples; more over this work includes the search for novel photogalvanic systems based upon reversible photoredox reactions of porphyrins and transition metal coordination complexes (11);

a research project that aims at the construction of solar cells, via charge transfers at liquid interfaces and another on the photochemical conversion by means of porphyrins and chloroplast elements (12).

2.2. *Wind Energy*

A perliminary evaluation of wind energy is based on meteorological records of the annual mean wind speed. The use of wind energy is assumed to be advantageous for speeds greater than 3.6 m/s. In Portugal, accounting for the necessary distance between turbines, the value of power density in regions where the harness is possible varies between 30×10^3 and $4\ 500 \times 10^3$ kWh/km^2/ /year.

2.2.1. *Conversion into mechanical energy*

This technology is well known in Portugal. The use of wind energy for corn grinding is no more meaningful but there are still some wind pumps in low deep wells for irrigation purposes. These pumps are manufactured in small work shops which also assure mounting and maintenance. The turbines for pumping are 3 meter diameter and the cost of harnessed energy lies between \$0.1 and \$5/kWh. These values are only competitive with electric pumps where the price of the power line is high as is the case for rural areas.

Taking in view the low performance coefficient obtained for this conversion, the power density lies in the range of 3×10^3 to 450×10^3 kWh/km^2 year.

2.2.2. *Conversion into electricity*

Small wind generators are commercialized in Portugal with power range of some tens of kW.

Research in several countries pursues at the moment the development of prototypes until 2 MW.

In Portugal, there are studies for wind system measurings connected with the problem of the turbine control (9). Also in course are some works for developing small size prototypes (14) (15).

The cost of the produced energy by big size wind turbines connected to the grid (without storage) can be \$0.05-\$0.1/kWh.

The performance coefficient is higher than in the case of 2.2.1., thus the power density is 9×10^3 - $1\ 300 \times 10^3$ kWh/km^2 year.

2.3. *Wave Energy*

An exhaustive inventory of wave energy in Portugal is not yet available. Nevertheless, a mean power of 50 kW per meter of wave front is an acceptable estimate. The wave energy conversion has been intensively investigated (namely in Great Britain and Japan). In Portugal, research efforts have been made on two conversion systems: numerical modelling on hydro-pneumatic systems (16) will be followed by laboratory testing of the numeric results (17). In the Autonomous Region of Madeira a prototype rides at anchor near Funchal, generating 0,37 kW to supply energy for lighting and signalling; a larger size prototype is expected to be concluded soon.

At the present development of the conversion technologies, the cost of the energy unit, can be predicted about \$0.06-0.07/kWh, assuming an efficiency of 15% for the conversion and transportation to the shore.

For this efficiency, the annual available energy after conversion into electricity will be, at the portuguese coast, about 70,000 kWh per meter of wave front.

2.4. *Tidal Energy*

The tidal energy amplitude varies in Portugal, between 1.7 and 4.1 m and is potencially convertible into electricity through conventional technologies, therefore excluded from the scope of research activities.

The cost of the energy produced depends essencially on the ratio between the basin lenght and the tidal amplitude, so much dependent on the specific conditions (geographical configuration, tidal characteristics,...). The cost of \$0.08/kWh obtained for La Rance power station in not meaningful. Cost estimates show that it is not economically competitive to produce energy with tidal amplitudes less than 8 - 10 m, which excludes the possibility of harnessing this resource in Portugal; hence a more detailed evaluation of the available energy is useless.

We must add that the conversion into mechanical energy can be, and has been used in a small scale with unsignificant contribution to the global energy balance either in the past or in the future.

2.5. *Ocean Thermal Energy Conversion (OTEC)*

In Portugal there is no research efforts on the OTEC technology. From the published data on ocean water temperature (18) near the pórtuguese coast the following conclusions can be extracted: the average temperatures on the surface are less than 20°C and, therefore, for a plant with an acceptable efficiency it would be necessary to have the cold source (4°C) at about 2000 m depth. These values show unfavourable conditions when compared with the tropical areas where experimental plants have been installed.

The cost of the produced electricity is estimated about $0.05-0.1/kWh. The typical plant size is expected to be around 250 MW with less than 1% efficiency. The available energy is in practice limited by the number of plants which can be built.

2.6. *Biomass*

Biomass is concerned with a great variety of resources, as well as with different conversion processes. The following potential sources of biomass can be used for energy production (in brackets the energy potencial in Portugal is given in 10^{15} J):

- agriculture residues (49.11);
- forest products and forest residues (34.75);
- urban and industrial wastes (9.33);
- animal wastes (8.96).

The main transformation processes are:

direct combustion, hydrolysis and fermentation, anaerobic digestion, pyrolysis and gasification.

2.6.1. *Direct combustion*

The process can be applied to forest products and residues, dry agriculture residues and several industrial wastes. Direct combustion is commonly used, implying, in some cases, adaptations due to the nature of the products, the energy obtained being heat and/ or steam and eventually electricity.

The energy cost varies between $40 and $120 /tep (for central electric power).

The evaluation of the available energy from combustion (and this is mainly true for all the other processes) is not easily quantifiable, unless some hypotesis are made about either the current use of existent resources on the foreseeable development of the several technologies involved in the transformation processes of biomass. Assuming that 50% of all available resources would be utilized for direct combustion, 1.5 Mtep of energy could be expected.

Within the current studies about direct combustion in Portugal, it must be mentioned an energy evaluation of forest products or residues, the working up of a model of soil utilization for energy applications and comparison of its economical value with competitive applications (19) and studies about utilization of wood and vegetable residues (20).

2.6.2. *Hydrolysis and Fermentation*

This process can be applied to agriculture residues and forest products and residues with a high moisture content (including the forest exploration residues), to obtain ethanol. The technology involved is well known, but a deeper insight is needed namely on the optimization of the energy balance, as well as on the transformation of particular substances (e.g., cellulose).

Energy cost varies between $600 and $1300/tep.

The ethanol production is controversial on an energy point of view. The energy input for ethanol production may be, in many cases, more than the energy output. Anyway the possibility of substitution of national resources for imported fossil sources, requires a more careful examination of ethanol production. The energy balance could be highly improved if renewable energies were used in particular phases of the ethanol production process (e.g. heat from straw or solar radiation energy), or if residues not currently utilized for other purposes were applied.

In this field, research work has been done in Portugal concerning the energy cost produced by hydrolysis of cellulose and alcohol production from starch (21).

2.6.3. *Anaerobic digestion*

This process can be applied to animal wastes, urban wastes (garbage and seweage), agriculture residues with a high moisture content and various industrial residues (e.g. food industry). Methane obtained from anaerobic digestion can be used to generate heat and/ or electricity, and mechanical energy

Energy cost is about $80-500/tep.

Assuming that 10% of all available resources would be used for biogas production (meaning approximately all animal wastes and a small quantity of other materials) a 100 000 tep potential can be estimated in Portugal.

Research work has been developed, namely studies on organic materials convertibility in biogas and efficiency of the conversion, (22), (2), improvement of anaerobic digestion prototypes (13), (13), studies on hydrogen and methane production models by biological ways (12), and evaluation of the energy potential of water plants (2).

2.6.4. *Pyrolysis*

Charcoal can be produced by wood combustion, which is a very old tradition in Portugal. Pyrolysis can be interesting for forest products, in particular for roots of holly oak, cork oak and olive tree.

Energy cost varies between \$20 and \$50/tep.

Assuming that 10% of all available resources would be applied for charcoal production, a 300 000 tep of energy can be expected.

2.6.5. *Gasification*

Methanol can be obtained from the transformation of synthesis gas produced by wood gasification. This process can be applied to forest products(eucalyptus), or other products in which moisture content is less than 25%. The gasification technology is well known and is similar to the methanol production from coal and natural gas. The energy balance seems to be more favorable that in the ethanol case but on the other hand, methanol has more utilization problems. The interest of this process lies in the fact that liquid fuels can be obtained from gasification.

Energy cost varies between \$500 and \$1000/tep.

2.6.6. *Other processes*

Other processes of energy production from biomass that seems somewhat interesting are the production of low Btu solid fuels from garbage, by separation and compactation; extraction of hydrocarbons from some kinds of plants, and biogas production from water plants, namely algae.

2.7. *Geothermal Energy*

The prospection and utilization technologies are commercialized. Some portuguese enterprises have been working on his field, although they never aimed to evaluate the energy potencial.

Geothermal fluids in Portuguese Mainland come from underground bassins located in fault regions and the ocurrence of high temperatures is not foreseen. Thus a foreseen application will be the space heating in houses and greenhouses.

In the Autonomous Region of Açores, the occuring high temperature led to the installation of a 3 MW thermal power plant and there are good perspectives to increase either the installed capacity or the total number of plants. This resource evaluation has been done associated with works to improve the current hot spring facilities.

The energy cost lies between \$0.03 and 0.06/KWh, the last value being refered to electricity production.

2.8. *Small scale hydroelectric power plants*

A basic study of resources in this area is now being undertaken. For the moment the potencial can be estimated in 8 TWh/year at a cost of \$0.8/kWh.

The technology for this type of resources is well known (our country uses hydroelectric power for a long time).

Nevertheless in order to decrease the cost to improve the competitiveness of this kind of plants, it is necessary to manufacture standart equipment and to simplify civil works.

3. INTERACTION WITH CONSUMPTION STRUCTURE

Renewable resource's penetration in the consumption structure depends on the final form of energy (heat or electricity).

Not taking into account the firewood case, that even satisfying around 6% on the portuguese energy needs is mostly burned near the prodution place and not through commercial circuits, it can be stated that energy from renewable resources has now an almost null expression on consumption, with the exception of hidroelectricity which contributes with 10% of the supply.

The repport "Procura de Energia em Portugal (Cenarios Alternativos)" shows that, even in scenarios involving very intensive conservation policies meaningful penetration of solar energy in the "Residential/Services" sector will not take place before 1985. Although solar flat plate collectors for domestic water heating are already commercialized. The same study states that during the period 1985-2000, a maximum of 20% of this sector's energy needs (350 000 tep) would be satisfied by solar energy.

Still in the form of thermal energy it can be foreseen in a non quantified form some meaningful penetration in the industrial sector (food processing, textiles, cork) and in the agricultural sector (drying, greenhouses heating).

Although data on commercialization of the involved technologies is lacking, it can be refered that part of the demand for low temperature heat generation (under 150°C) representing 23% of total energy demand is already susceptible to be supplied by low concentration rate solar collectors.

The irregular form in which energy from new and renewable resources is available, severely limits the production of electricity, given the storage difficulties of this type of energy.

In fact, the high level of reliability expected by consumers limits the contribution of renewable resources in this final form to the base load diagram, without significant reduction on conventional equipment investments, but with the possibility of fuel savings. Thus, economic viability of the plants based on renewable resources when connected to the grid is conditioned mainly by the cost of base load energy (lower than the average price of electric energy).

On the contrary, there are promising conditions for descentralized produced electricity penetration. In Portugal, about a million people are still living in regions not connected to the power grid; then, the rural electrification program can be supported by small electric power units which output cost competes fairly well with the cost of electricity supplied by the grid, because this last system is hardly covered by the typical small consumption of such areas.

4. IMPLEMENTATION. BARRIERS AND CONSTRAINTS. ENERGY POLICY ACTIONS

4.1. *Political constraints to the implementation of renewable resources*

The main condition for the implementation of renewable resources conversion technologies are the progress of fundamental and applied research, the technological development of envolved processes and the commercialization capability of the economically competitive technologies.

The factors to stimulate this progress are:

a. Availability of human and material means to perform the necessary research and development efforts;

b. Existance of potencial users of the developed technologies;

c. The capacity of these technologies to be commercialized.

This last factor depends on:

a. The research and development progress in order to demonstrate the competitiveness of each technology against conventional alternatives;

b. The conditions for market penetration to be satisfied against difficulties like institutional constraints or resistance to inovative products.

National and international political actions are necessary to remove such constraints, which add up to the inherent constraints (capacity of energy conversion and cost of produced energy), on the following areas:

(i) mobilization of funds to support the research and the incentives to the consumers of produced equipment taking into account the capital intensity nature of the investments;

(ii) information to the potencial consumers in a way that they will be able to evaluate quantities and costs of the energy produced by these new technologies (the notion of cost involves hereby social and enviromental factors);

(iii) generation of conditions for skilled technical and scientific education, assuring the proper means for know-how transfer either at research and development levels or at commercial production level;

(iiii) removal of institutional constraints (e. g. current legislation) in some way restrictive to the increasing use of renewable resources.

To be effective, the intervention of national or international policies on these areas must be based on an efficient coordination of the activities (from fundamental research to manufacturing and commercialization) by responsible entities which must define the priorities for the financing, the spread of information, the manpower education and the remotion of institutional constraints. In order to achieve this general purpose some concrete measures are next refered.

4.2. *Energy Sector National Policy*

The following measures were already announced namely for the short term plan (1981-84), concerning the implementation of renewable resources in the context of measures of contention and progressive reduction from foreign dependence on energy sources and promotion of national resources utilizations:

a. Building codes for energy conservation in houses;

b. Harnessing agricultural urban and industrial wastes with energy value;

c. Incentives for use of renewable resources if they have economic value for the country;

d. Coordination of the R, D & D plan on new technologies namely for harnessing national resources.

These tasks bring out the need for a coordination institution that would define the priorities in energy planning for the short, medium and long term.

4.3. *International Organizations Energy Policy*

International policies may favour the implementation of renewable resources conversion technologics; the importance of information exchange, cooperation in the research fied, technological development or demonstration projects or instalation of large scale plants, are recognized as effective forms of technical and scientific know-how transfer, necessary to amplify the extent of renewable resources utilization.

From international organizations which must issue recommendations about cooperation mechanisms, some support is expected, not so much of financial nature (assuming that existing credit institutions are apparently sufficient to correspond to the production capacity of research and project institutions), but mainly on the establishment of adequate structures for the exchange of information and the technical and scientific education, necessary to allow a minor dependence of less developed countries on the more developed ones.

Recommendations aiming to the creation of institutions that, in connection with national coordination entities, (i) could assure information diffusion about R, D & D on new technologies, (ii) could enable a more adequate formation of scientists and technicians concerned with renewable resources conversion processes (e. g. creation of regional institutes), (iii) could assess the interest and define priorities about international cooperation projects, are examples of important contributions from the United Nations Conference on New and Renewable Sources of Energy, to achieve a more extensive and conscious contribution of the renewable resources to the future energy supply system.

APPENDIX

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