N82 22680 AN OVERVIEW ON EUROPEAN SPS ACTIVITIES

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1. Introduction

Satellite Power Systems have now been studied in Europe for at least six years. Both national and international government agencies and industry have been involved in evaluating the potential contribution of an SPS to the European energy supply and to assess the potential impact on European industry of European participation in an SPS programme. So far this effort has been at a much lower level than in the United States. A large part has been a critical review of the work performed in the United States, but in addition an effort has been made to identify problems that would be specific to a European application of the SPS and to study possible solutions to these problems.

To assist understanding of the complicated institutional framework in which European SPS activities take place, it is useful to review first the organization of space and energy research in Europe before describing the activities themselves in more detail.

In Europe space research and space technology development is pursued at both an international and a national level. Most of Europe's international space activities are the responsibility of the European Space Agency (ESA), which was formed from the two earlier European space organizations: The European Space Research Organisation (ESRO) and the European Organisation for the Development and Construction of Space Vehicle Launchers (ELDO). ESA's Member States are Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden, Switzerland and the United Kingdom. Other countries, e. g. Austria, Canada and Norway participate in selected Agency programmes. In addition to the joint European programmes, several of ESA's Member States have national space projects, which they conduct alone or bilaterally with other European countries or with the United States.

In space research and technology development, the joint European programmes of ESA represent the major part of the overall European effort. The situation is very different for energy technology. There are joint European programmes, mostly funded through the Commission of the European Communities, but they represent only a small part of the total effort in Europe, which is mainly controlled at national level. The major energy activities of the European Communities are the Joint European Torus (JET) experiment on thermonuclear fusion and the work at the Joint Research Establishments concerned mainly with nuclear-energy-related research.

In addition to the Communities programme, several European countries participate on an individual basis in energy research projects organized under the auspices of the International Energy Agency (IEA) of which most Western countries are members, including the United States and Japan.

2. The European Energy Situation

Only thirty years ago Europe was almost self-sufficient in energy. Since then, however, its consumption has more than doubled and the additional demand has had to be met with imported energy, mostly in the form of oil and gas. Recent events have demonstrated just how dangerous this import dependence can be for economic and social development, and all countries in Europe have been prompted to initiate large-scale research and development programmes aimed at reducing their dependence on imported energy.

Growing public awareness of the limitations and drawbacks of each of the available energy sources has led to recognition of the fact that no single source will be able to meet even a major part of our energy demand in the future. The non-renewable sources such as oil, gas, coal and uranium, and the renewable or almost inexhaustible sources such as wind, hydro-power, biomass, direct solar energy conversion or nuclear fusion, are all limited in their use by geographical, environmental, economic or political factors. Compared with other parts of the world, Europe is in a particularly difficult position because most of its primary energy resources, such as oil, gas and geothermal energy are relatively small, while coal reserves are relatively large but difficult to mine, uranium is scarce, and even sunshine is not very abundant.

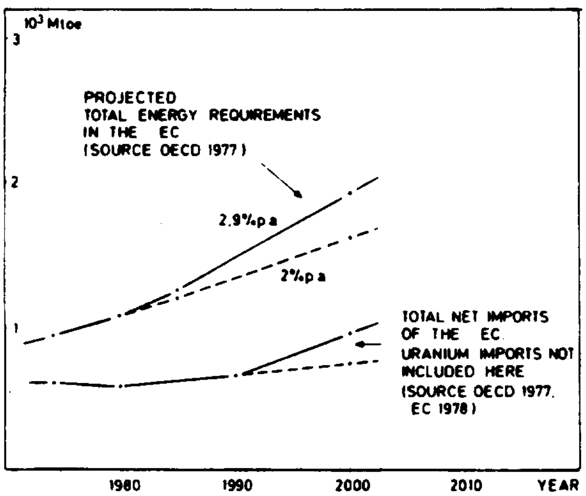

Figure 1

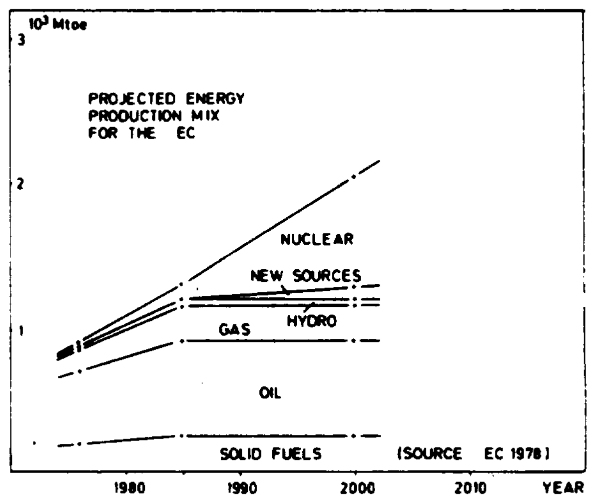

Figure 2

Europe now imports between 50 and 60% of its energy needs. Figure 1 (1) shows the projected energy demand in the European Economic Community (EEC) and the estimated import needs. Figure 2 shows a more detailed projection of the expected energy mix (2,3). Bearing in mind that most of the uranium has also to be imported, this projection indicates an even larger EEC dependence on imported energy in the future. Europe's precarious energy situation can be illustrated by the fact that at present, the indigenous primary energy production per capita in the United States is more than 2,5 times that in Europe and this ratio will probably increase with time, in view of the much larger fossil fuel resources in the States.

Unfortunately, it will also be more difficult for Europe to develop the use of renewable energy sources. For example, the average annual insolation in central Europe is about 1000 kWh/m2, compared with 2500 kWh/m2 in Arizona. Southern Eur-pe has higher insolations, up to approximately 1700 kWh/m2 in Southern Spain, but in most parts it would be very expensive and, because of the need for very large capacity storage, technically difficult to use solar energy for electricity generation. In central Europe the cost of solar electric power would be more than 2,5 times higher than in large areas of the United States, considering that the installation cost of a solar electrical generation plant is more than inversely proportional to insolation for a given capacity.

The EEC's energy-supply projection foresees some contribution from new sources or technologies other than fossil fuels and nuclear energy (3). It is estimated that these may provide 2-5% of the energy needs in the year 2000, but none are expected to have a significant impact on Europe's overall energy supply. The total contribution from solar energy is not expected to be more than 1 or 2%, compared with 20% in the United States' plans.

3. Status of European SPS Activities

Investigation of the SPS concept started in Europe approximately six years ago and National Agencies as well as the European Space Agency have tried to evaluate its viability for Europe. Most of the studies were initiated by departments or organizations associated with space research and technology. The energy departments of European governments have so far not shown any great interest in the idea.

The first significant effort was a detailed study of the SPS concept performed under a contract from the German space research organization (4). The work was performed in 1974/75 and its results were used and further extended in an extensive analysis of the use of solar energy in general, which was performed by a group of German firms and research institutions under contract from the German Ministry of Research and Technology (BMFT). This later study (5) led to the conclusion that for a country like Germany the potential advantages of an orbital solar power station are significant when compared with terrestrial solar power stations, since the relatively small amount of solar radiation energy available at the earth's surface, together with the unfavourable annual variations makes use of terrestrial solar power plants not very attractive. It was also pointed out, however, that a number of basic questions had to be investigated before specific technical problems should be studied. Examples of the basic questions raised were the environmental aspects, the cost of space transport and solar-energy conversion, the feasibility of controlling very large structures in space, and the analysis of alternative technical SPS configurations. However, despite the rather positive assessment of the SPS compared with terrestrial solar electrical power generation, the German Government did not continue its investigation.

More recently the Department of Industry in the United Kingdom funded a study of the SPS as part of an investigation of the industrialization of space. This study (6), which was completed early in 1979, discussed the technological and environmental aspects of the SPS as well as its potential contribution to the European energy supply. It also addressed the economic and political issues involved in the manufacture and operation of the SPS.

The conclusion was that the problems associated with the SPS were no different in scale from those associated with other options for supplying our future needs of baseload electricity, e.g. fossil fuel burning or nuclear fission. Any difference was thought to lie more in the nature of the mix of problems associated with the different energy sources than in their absolute magnitude. The study also recommended that, prior to making any significant financial commitment to SPS specific technology development, the United Kingdom should first investigate such basic issues as:

- the advantages and disadvantages of adding the SPS to existing or projected candidates for future baseload electricity supply
- the possible locations for rectennas for meeting European power needs
- the environmental impact of SPS operation
- the probable timescale for technology development and operational applications.

Late in 1979, the UK Department of Industry awarded a further contract to a group of companies led by British Aerospace, to study the implications for UK industry of the implementation of Solar Power Satellites. The major objectives of this contract are:

- to assess and identify all direct and indirect design areas and hardware technologies involved in SPS development and operation
- to identify potential opportunities for UK industry
- to attempt to quantify these opportunities and to recommend future actions.

In addition, British Aerospace has initiated an in-house effort to investigate certain technical aspects of the SPS that are particularly critical for Europe:

- Study of several methods for reducing the rectenna area, e.g. combination of laser and microwave power transmission by using a stratospheric platform to convert laser energy into microwave energy or splitting of a 5 GW beam into several smaller beams.
- Assessment of radio-frequency interference, both with ground and spaceborne communication systems, and definition of possible mitigating approaches.

In France, M. Claverie and A. Dupas of Centre National de la Recherche Scientifique (CNRS) have investigated the SPS's potential role as a solar-energy conversion system compared with terrestrial solar power plants. They first made an assessment of the potential World market for terrestrial and space solar power stations (7) and came to the conclusion that solar electrical power generation in space and on the ground can complement each other. This conclusion is based on the assumption that a large part of the electrical power needs have to be supplied by large centralized baseload power stations, including power satellites, but that in addition there is a significant market for decentralized electrical energy generation, mainly in areas that have high insolations and/or lack a power grid infrastructure.

More recently Claverie and Dupas (8) have studied in greater detail whether the SPS is the only practical option for generating baseload electrical power from solar energy. They compare SPS and terrestrial photovoltaic energy conversion plants, in combination with storage systems to provide continuous power-generation capability. The preliminary conclusions are that terrestrial photovoltaic power stations may be able to compete with SPS stations as baseload power plants, both in terms of investment cost and land requirement in locations with high insolations such as the Southwestern parts of the United States, but not in central Europe. They recommend further study of this issue.

The European Space Agency started to assess the SPS concept in 1977. Following an initial compilation of the literature, the Agency's work has been oriented in three main directions:

- collection and distribution of technical information on the SPS in order to stimulate a discussion on the potential role of an SPS in the future European energy scenario
- identification of those aspects in the development and operation of an SPS that would be different in the United States and Europe
- study of selected SPS technical problems in order to identify possible areas for European research and technological development.

As a part of the dissemination of the technical information being gathered, a number of articles (9,10) have been published in ESA journals and a round-table discussion has been organized (12). The SPS was also discussed in a position paper prepared for the Agency's Member States and used as an input to the 1979 WARC, proposing consideration of the SPS by allocating an adequate frequency band to energy transmission (13).

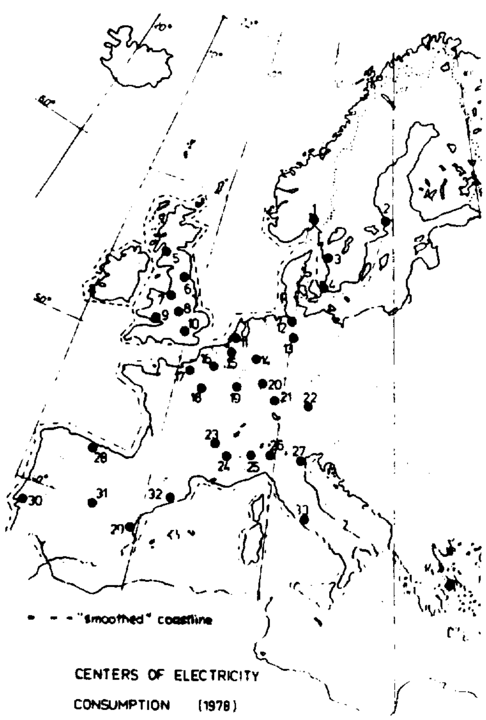

Figure 3

In 1979, J. Ruth and W. Westphal of the Technical University of Berlin performed a preliminary study (14) of the European aspects of solar power satellites under ESA contract. Some specific European factors were identified in this study.

The Western European countries lie in the longitude range 24°W to 30°E, and in the latitude range 36°N to 72°N. This area is not only considerably more northerly than the United States, but it also includes a considerable number of East European countries, a fact that could give rise to serious political problems.

Most of the major centres of electricity consumption, defined as circular areas of 100 km diameter and with consumptions of more than 3 GW, lie roughly between 45°N and 55°N (Figure 3). If SPS rectennas were to be placed near these major consumption centres, very large tracts of land would be needed. Even without longitude offset, the size of a rectenna and associated safety zone at 53° latitude would be almost twice as large as at 30° latitude, taking the beam geometrics of the United States' reference system as a guide (17). The long axis of the ellipse forming the safety zone (corresponding to a maximum microwave intensity of 1 mW/cm^2 with the beam energy distribution defined in the United States' reference system) would become 44 km instead of 26 km with a short axis of 20 km. The area would grow from 400 to 730 km^2 as shown in Figure 4. The situation would be worse if longitude offset had to be included, because most of the major consumption centres lie between 5°W and 10°E.

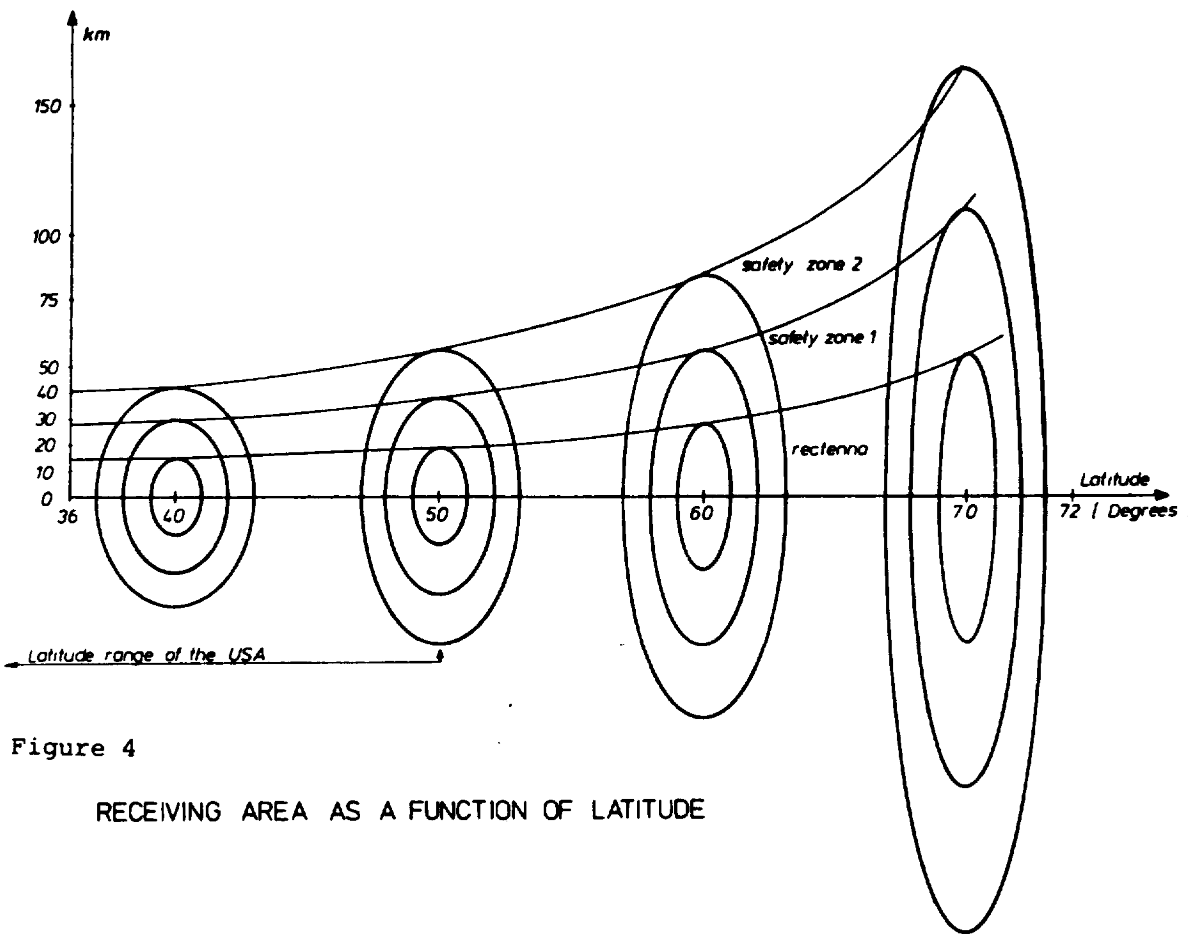

Figure 4

RECEIVING AREA AS A FUNCTION OF LATITUDE

Because of the high population density in the European region with the highest electrical power consumption, it would not be possible to place rectennas of the size defined in the United States' reference system near the consumer, without moving considerable numbers of people. As Figure 3 shows, European conditions are more favourable for placing rectennas offshore. More than 80% of the major consumption centres are located within 300 km of a coastline. In addition, large parts of the relevant offshore regions are relatively shallow, with depths of between 10m and 50m.

Since the land for rectenna sites is so severely restricted and European industry has considerable experience in the construction of offshore structures (from the North Sea oil exploration), the problem of siting rectennas offshore has been further investigated by P. Collins (16).

Neglecting the specific problem of interfacing power satellites with a utility grid, the 5 GW per unit of the United States' reference system does not seem to be a problem in itself. At present, there are already blocks of three to five nuclear power plants with capacities of 1 GW each in the planning stage in several European countries. The national grids in Europe are also widely interconnected. In addition to the member states of the UCPTE (15) (Union for the Co-ordination of the Production and Transport of Electrical Energy) Austria, Belgium, Federal Republic of Germany, France, Italy, Luxemburg, Netherlands and Switzerland, Spain, Portugal, Yugoslavia, Denmark and Greece are connected to a European network.

The United Kingdom and the Scandinavian countries are also connected to the UCPTE grid, via direct current lines.

The exchange of electrical energy between national grids is constantly increasing. In 1977, 51,000 GWh, corresponding to 5.9% of the total electricity generated, were exchanged between the UCPTE member states alone. The maximum power exchange at any given time during 1977 between UCPTE countries was 8.3 GW. The capacity of the lines crossing the borders of the Federal Republic of Germany, for example, was 21,600 MW in 1977.

In addition to restrictions imposed by the size of the sites needed for rectennas, the potential contribution of an SPS to the European energy supply could also be limited by spacecraft orbital location constraints. West to East Europe extends from 10°W at the West coast of Ireland, to 25°E, at the West coast of Turkey. It is not yet clear what the minimum separation for power satellites in geostationary orbit would be. Preliminary estimates assume a separation of 0.5° corresponding to a maximum of 70 satellites in geostationary orbit within the longitudinal boundaries of Europe. In practice, the number available to Western European countries would be lower than this because of the needs of East European or African countries falling within the same longitudinal band.

The availability of orbital space may become an important factor in the assessment of Europe's interest in the SPS. It has been estimated (14) that the minimum energy production from the SPS necessary to justify the development of such a technology would be approximately 10^3 TWh/year, which corresponds to the EEC's present electrical power consumption. This lower limit would call for approximately 25 satellites, each with an output of 5 GW.

4. Prospects for European Activities

Any future European activity in the SPS field will be strongly influenced by the fate of the SPS project in the United States. A significant effort in Europe can only be expected if the United States' Government decides to continue and increase its SPS activities beyond the present three-year assessment phase. Until this decision is taken, the European effort is expected to continue at its present level. ESA will continue system studies with the major aim of investigating possibilities for reducing the surface area needed for rectennas. ESA is also planning to study the impact that an SPS technology and development programme would have on the European space programme.

A major step in such an analysis will be the selection of areas for potential European activities, assuming that Europe would participate in a joint international programme. Typical selection criteria for early programme phases would be:

- that results are also applicable to other European space programmes
- that Europe has a significant technological advantage in a subject
- that the results of the activity are very important for SPS programme decisions in Europe
- that a high production volume with a large "added value" could be expected.

Any future technological research in Europe can make use of a well-established infrastructure, both in space and in energy technology. Europe's space programmes started more than fifteen years ago and the national and international budgets for space research and technology are presently of the order of $1,150 million per year. European space activities embrace the whole spectrum of space technology, supporting complex scientific missions, satellite communications, spacecraft, launcher development and the manned Spacelab. (11).

The availability of the Ariane launch site at Kourou, French Guyana, which is ideally situated for launches into geostationary orbit, might prove particularly interesting. The low latitude and low population density associated with this site could represent substantial advantages for an SPS programme. (Figure 5).

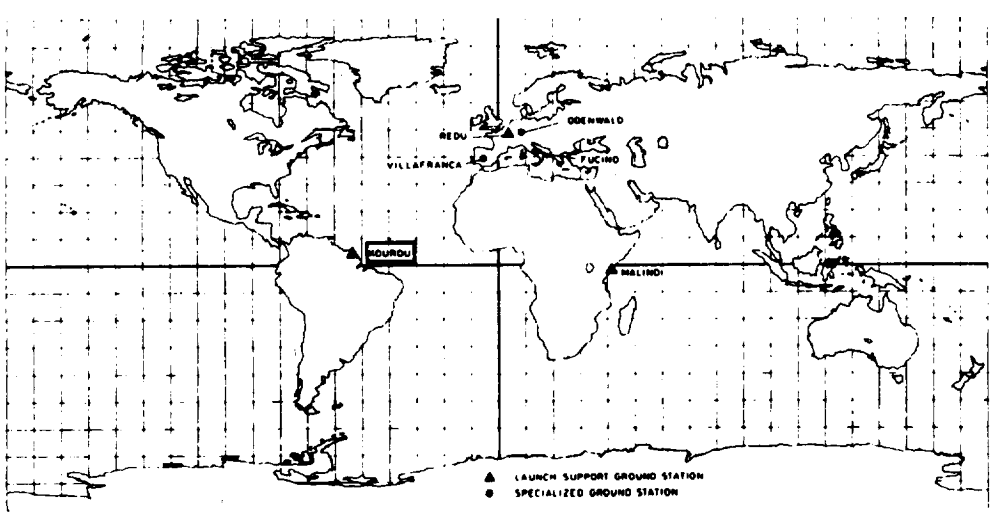

Figure 9 - European launch site, Kourou, French Guyana

In addition to investigating the potential impact of an SPS technology programme on European space activities, ESA will continue to promote the assessment of the SPS concept in Europe through the organization of working groups. The present lack of communication between space and energy organizations makes it very difficult to come to a comprehensive understanding of the potential benefits and penalties of using the SPS as part of the European energy supply.

5. Conclusions

At present, Europe's energy needs are satisfied mainly by oil, coal, and natural gas. More than 50% of this energy is imported, mostly as oil. Current predictions assume that the demand will grow and that Europe will continue to import at least 50% of its energy needs.

In view of the unfavourable geographical and climatic situation of large parts of Europe, terrestrial solar energy conversion is unlikely to make a significant contribution to Europe's future energy supply. The use of solar energy via the SPS approach could therefore prove to be of major interest if its technical, economic and societal viability can be demonstrated for European conditions.

The SPS is being studied in several European countries and by ESA. The total effort has been considerably smaller than in the United States, but a number of specific European aspects have already been identified and will be studied further. Because of the compactness and much higher population density of Europe, it will be very difficult for example to find suitable rectenna sites on land. Reduction of individual rectenna areas and/or the placing of rectenna offshore will be very critical as far as the acceptability of the SPS for Europe is concerned.

Part of the European studies involves analysis of the role that Europe might want or might be able to play in an SPS technology and development programme. Europe has a good space-technology infrastructure combined with considerable experience in planning and executing international space projects and this could form the basis for strong European participation in a joint international SPS venture with the United States and other countries. A specific European problem is the fact that there is no European equivalent to the Department of Energy in the USA which could co-ordinate and fund the European elements of an SPS programme. Based on its technical expertises and its experience in the management of large international projects, ESA could undoubtedly play a major role in any future European SPS activities and it will therefore continue to investigate system aspects and selected areas of relevant space technology.

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