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Comparizon of various energy systems and their roles
多様なエネルギー源の比較とその役割

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There are various requirements for future energy sources. Features of three options of advanced energy technologies (solar/wind, solar power satellite and fusion) , which are expected to satisfy the most part of these requirements, are considered. Each option has various merits, but at the same time, no prospective energy option satisfies the requirements completely, i.e., every option has a certain degree of drawback(s). An optimized combination to make the best use of these technologies will be required.

1. Introduction

Based on recent resource survey [1], we can believe that the resource of fossil fuels and other hydrocarbon resources will not run out during the 21st century and possibly the next century, too. On the other hand, a lot of reports have been pointed out a possibility on the climate change in near future due to the use of the fossil fuels. We need new energy sources or advanced energy technologies which emit less CO_2 during operation, in order to reduce the CO_2 emission rather than the restriction in resource of fossil fuel. Therefore, such future energy system should be satisfy various requirements, not only the abundance in resource.

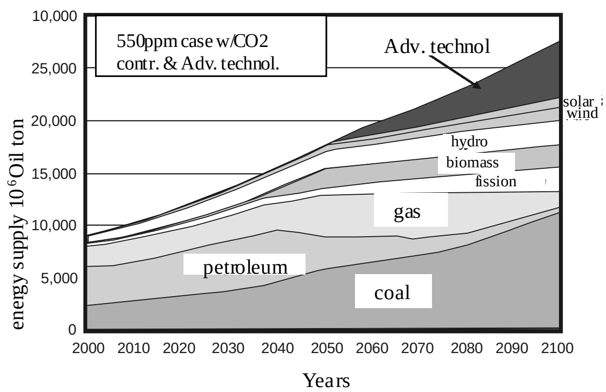

Fig. 1 Energy supply ant its breakdown

One of our good targets for the next 100 years is '550ppm in CO_2 concentration at 2100', which was shown by IPCC in 1995. An example of a typical scenario of energy supply to achieve the above target is shown in Fig.1 [based on the report of work by NEDO/RITE, 1998]. From such perspective, we can see that any advanced energy technology should be available, at latest, until the middle of this century. If not, such energy technology may not make any significant contribution by 2100. Here we note that a period for replacement of energy infrastructure by a new technology takes a lot of years, 20-30 years usually.

2. Options of advanced energy technology

We can consider the followings may be the major requirements to be posed for the future energy technology which will be used as basic power sources:

1. Abundant and widely available resources
2. Low emission of CO_2 as well as other undesirable substances and less waste to be disposed
3. Acceptable cost with flexibility in plant scale
4. Stable power supply and less vulnerability to international affairs
5. Safety and security

In this review, we consider roles of following three options of advanced energy technologies that may satisfy the most part of these requirements;

1) Terrestrial solar and wind power plants
2) Solar Power Satellites (SPS) on Geosynchronous Earth Orbit (GEO)
3) Fusion reactor

3. Characteristics of the options

3.1 Resource

Since the reserves of resource or available energies is unlimited for any above options. But, when we see them in practical conditions, there are some issues. The available energy from solar power and the available area for wind power depend on the country [2]. Since the rectena (a power receiver on the earth) of SPS is large ($60m^2$/GW) [3], the terrestrial area can be a restriction. Total power generated by SPS will be limited by capacity of the GEO. The initial construction pace of fusion plants will be restricted by the tritium breeding ratio[3].

3.2 Environmental Issue

The CO_2 emission from all candidates is low enough. However, concerning the disposability of waste, the solar/wind power plant may be the best. On SPS, there is a concern on how to dispose a satellite ($2x10^4$ tons [4]) on GEO. The waste from fusion is $2x10^4$ tons throughout the plant life and it is radioactive [5].

3.3 Cost and plant scale

Any energy plant should be provide the energy within energy cost competitive with others. But, it is also true that there are many unknown factors on the cost of prospective energy, then, we do not discuss here the issue on the direct cost of plant.

Flexibility in plant scale (with acceptable cost) is another issue. The solar/wind is very flexible in minimum plant scale. This is an important merit for solar/wind plant. Although there is no inherent limit for plant scale for SPS, a strong scale effect in cost will exist because the size of antenna and rectena seems to be determined by the beam divergence rather than the transmission power. Minimum scale of magnetic confinement fusion will be restricted by the inherent feature of fusion reaction. Large power consumption at start- up can be another weakness of fusion, especially in the area on poor electric network. If laser fusion mitigates these weakness, it may bring about an important break-through and increase the value of fusion energy.

3.4 Stability of power supply

Concept of stability includes two issues. The first one is related to the inherent operational restriction. The second issue is vulnerability of operation to international affairs.

For the fusion, there is no limit for continuous operation, at least, in principle. The output of SPS is interrupted due to eclipse by the earth before and after the autumnal and spring equinox, but the duration of interruption is less than one hour per day. The solar/wind power plant is inherently unstable. The cost to overcome this unstable feature will be expensive. On the other hand, the solar/wind power plant is highly invulnerable to international affairs. The fusion will be invulnerable enough, because fusion fuel can be obtained from seawater and the fuel cycle can be closed in an unit plant. Since the GEO will be shared among foreign countries, the SPS plants on the GEO might have some vulnerability.

3.5 Safety and Security

The solar/wind can be regarded as having no hazard potential. In the case of SPS, there might be some unfavorable effect by electromagnetic wave near the rectena. The power density on the rectena of SPS is $23mW/cm^2$[6]. The fusion plants have a hazard potential due to associated radioactivity. The bio-hazard potential of fusion is, however, lower by 1/1000 than the present fission plant[4].

4. Roles of the options

As shown above, each option has various merits as well as weakness, and no option satisfies all the requirements completely. Therefore we have to use them under the best-mix-policy. Some possible roles for the options considered by the author is shown in Table 1. A path to the economical and ecological future will be created by an optimized combination among such advanced technologies.

References

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Table 1 Characteristics of three options considered and possible roles for their best use

	possible roles	issues for expansion into wide use
solar/wind	effective & maximized use in good condition area	stability in the electric network
SPS	base load use, H_2 production, usable for area on poor network	limit in generating power by the GEO capacity
Fusion	base load use, H_2 production, siting near consuming area	limit in initial construction pace by Tritium breeding