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The contribution of fusion to sustainable development

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Abstract

The world demand for energy is projected to more than double over the next 50 years, indeed this will be essential to bring much of the world out of poverty. At the same time there is increasing pressure to substantially reduce atmospheric pollution, most notably of carbon dioxide. Together, these conflicting goals drive a need to produce enormous amounts of non-carbon energy supply, much greater than our total present energy supply. This presents a huge challenge. As one of very few options for large-scale, non-carbon future supply of energy, fusion has the potential to make an important contribution to sustained energy supplies. Fusion's advantages of large fuel reserves, low atmospheric emissions and high levels of safety make it an important consideration in future energy strategies. Conceptual designs of fusion power plants have been optimised against safety and environmental criteria; the results are described here and the outcomes compared with other energy sources. To make a contribution to sustainable development, fusion must be economically viable in a future energy market. The calculated costs of electricity from fusion show that, particularly in an energy market where environmental constraints are playing an increasing role, fusion can make an important contribution.

Keywords: Energy; Sustainability; Fusion; Environment

1. Introduction

The key areas that determine the contribution that an energy source can make to sustainability are the availability of materials (including fuels), the associated hazards, from emissions, waste and accidents, the potential capacity of the energy source, the social acceptability and the costs. The issue presently of greatest concern relates to carbon emissions and climate change. The way that fusion performs in each of these areas is discussed and found to be favourable.

2. Carbon emissions

The ongoing and projected increase in world energy demand poses a stark contrast to the pressing need to reduce carbon emissions. There are many technologies which can be brought to bear on this problem; fusion is only one of them. Nonetheless it is instructive to look at the issues and timescales to see how

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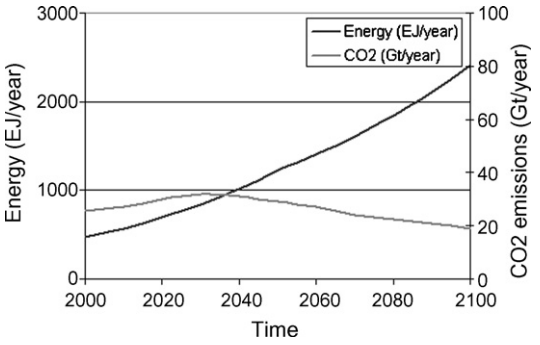

Fig. 1. To stabilise atmospheric CO_2 concentration at 550 ppm requires a progressively stronger decoupling of energy and carbon emissions over this century.

fusion may contribute. Fig. 1 shows an illustration from modelling reported by the Intergovernmental Panel on Climate Change (IPCC) [1] for an atmospheric CO_2 concentration stabilised at 550 ppm, combined with an illustration of possible future energy demand [1]. There are two important timescales: out to around 2040 the challenge is to halt the growth in CO_2 emissions in spite of the increasing energy demand; beyond that there is the need to substantially reduce CO_2 emissions whilst still meeting an increasing energy demand. Broadly, fusion is targeted at the latter challenge, however if fusion could be brought to market through an accelerated "crash" programme, it could begin to contribute also to the former challenge.

3. Fuels and materials

The basic fuels for fusion as presently pursued are deuterium and lithium, the latter used to generate tritium in the blanket. There is an essentially unlimited supply of deuterium in water (enough for billions of years of energy supply), so we only consider here the limitations that could result from lithium supplies.

An important part of what follows relates to the competing uses for lithium. In the figures below it is assumed that fusion uses only one isotope of the lithium, Li-6, which makes up 7.4% of natural lithium. This is a conservative assumption. Consequently, although the figures below assume that fusion can access all the lithium reserves, nonetheless 92.6% of the lithium remains available for other uses, which do not depend on the isotope.

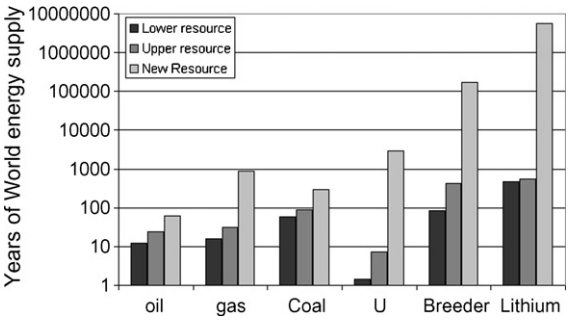

Fig. 2. Estimates of fuels available for different energy systems compared to present annual energy demand globally.

Fig. 2 shows estimates of resources [2–6], in terms of years of total world energy supply (at the present rate), for different forms of fuel-based energy, including established reserves, the estimated resource, and additional supply from completely different, sometimes speculative, considerations. This latter category includes non-conventional oil, methyl clathrates for gas, uranium from sea water, and lithium from water.

The main results for fossil fuels are that, in the absence of methyl clathrates, there is 100 up to 300 years of present energy supply, primarily in coal resources. This ignores other limitations that may apply to carbon emissions or other pollutants.

The more surprising results come in the uranium data, when used in thermal fission plants. Although uranium from sea water could supply thousands of years of energy, the present reserves are sufficient for only 1–10 years of world energy supply. This is not to suggest that we are running out of uranium; at present levels of consumption, this is sufficient for 30–60 years, however large growth of nuclear power would benefit from establishing further resources, perhaps through use of lower concentration ores. Failing that, a switch to breeder technologies may be necessary for fission to expand substantially.

The least constrained energy source in terms of fuel availability is fusion, with lithium supplies sufficient for thousands and up to millions of years of total world energy supply.

Because fusion uses very little fuel it is possible that the use of other materials in the construction of the machine may pose a more important limitation and we must investigate, if that is the case, how these could be circumvented. Two materials that are found to be quite