Why we need fusion energy…

…and how Sweden and Europe can contribute to its realisation…

There is presently no single energy source that is sufficiently powerful, sustainable, clean and economically viable to adequately meet the world's energy needs – and there will probably never be one. Instead, we need a palette of complementing energy sources in which fossil fuels are excluded. It is widely believed that renewables alone will suffice. For regions such as Europe this is, however, a misconception. In this article, we will explain why and show how fusion energy can fill the gap. However, time is running short, and present national and international research and development resources that are spent on fusion may not be sufficient for fusion to be ready in due time.

Renewables do not suffice

If Europe wants to become free from burning and importing climate changing fossil fuels, several obstacles need to be addressed:

- Power consumption is high at 5kW/person (world: 2kW/person);
- Population density is high at 112 people/km^2 (world: 13 people/km^2);
- Land area for renewables is limited as over 30% is already cultivated (world: 11%);
- 54% of consumed energy is currently imported (87% of this is oil and gas).

These are serious problems that complicate the transition of energy production from fossil fuels to sustainable energy sources. Not all renewables satisfy the sustainability requirement to 'meet the human needs of the present without compromising the ability of future generations to meet their own needs'. Examples are the excessive exploration of hydropower and the production of ethanol (biofuel). In a major study (Energy Futures: The role of research and technological development, 2006) the European Commission found that renewables can only, when fully developed, supply about 50% of the energy needed for Europe. One reason for this is the extreme land requirement, in particular for biofuel that only has 1% efficiency when converting sunlight to biomass.

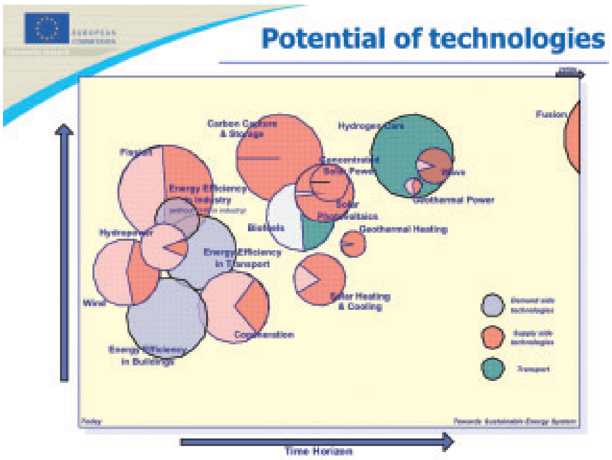

Fig. 1: The path to fossil-free energy production in Europe includes fusion. From the Strategic Energy Technology Plan (SET) by the European Commission

Renewables will certainly become important in Europe and in the world. But most of them suffer from a serious problem: they are intermittent and controlled by nature's whims. Wind and wave power, solar cells and others do not provide baseload energy. A number of solutions to this problem have been suggested, such as hydrogen storage. It has even been suggested that solar power from the deserts of North Africa could provide Europe's needs via smart grids.

However, these suggestions suffer from two serious flaws. The first is economical – the introduction of energy storage infrastructure or extensive expansion of electricity networks would approximately double the already high costs for renewable energy production. The second is that history has shown how regions with strong concentration of energy resources have become sources of political turmoil – it is in the interest of the world's nations to produce their own energy.

Fusion and renewables – the sustainable solution

If fossils are to be phased out, and renewables do not suffice – where should we turn? Two options come to mind: fission and fusion. Fission faces serious and well-known problems with public acceptance due to risks of radiation and the transport of radioactive material, as well as the coupling to proliferation. Additionally, the fuels – uranium and plutonium – are rapidly becoming scarce. The fission industry has responded with generation III and IV reactors to produce additional fuel. Most likely, these will again meet public resistance due to the high costs/waste and the risk for proliferation.

Fusion, however, has the potential to become just what we need: emission and pollution-free baseload energy that is sustainable for hundreds of thousands of years, safe and economic. Fusion is the basic energy source of the universe; it is the process in which the sun and the stars produce heat and light.

On a microscopic scale, thermonuclear fusion occurs when hydrogen ions are confined in magnetic field bottles at high temperatures as 'plasmas'. Their high speed brings them close together so that they can 'fuse'. In the reactions, vast numbers of helium

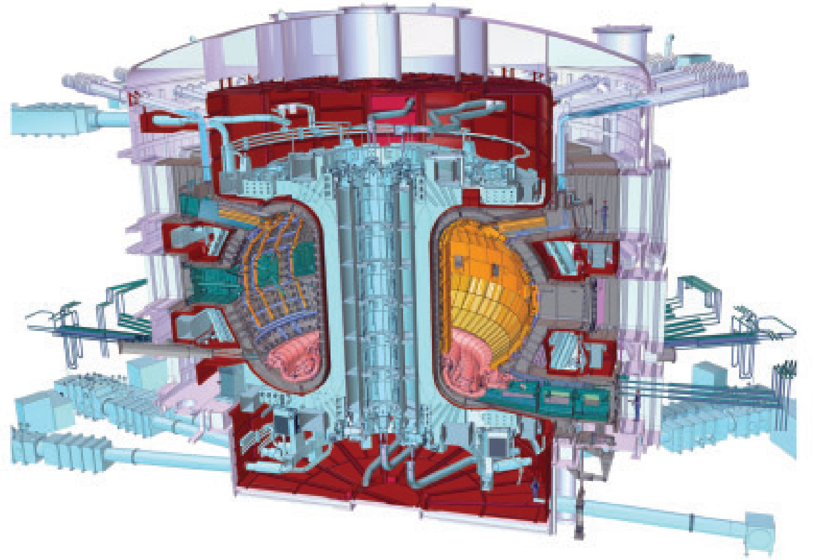

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Fig. 2: The ITER machine is based on the tokamak concept of magnetic plasma confinement, in which the fusion fuel is contained in a doughnut-shaped vessel. With a height of 29 metres and a diameter of 28 metres, ITER will be the world's largest tokamak

nuclei and neutrons are created. The neutrons carry large amounts of kinetic energy, which is retrieved as heat in the surrounding walls. This heat is then used to produce electricity.

The largest experimental, so-called 'tokamak' fusion reactor to date is in Abingdon in the UK, called JET; but a new, larger fusion reactor, ITER, is currently being created in France and is scheduled to be in operation by 2019.

Enhanced fusion funding cannot wait

As with many R&D projects, funding has become an issue; but in the case of fusion, the potential gains from increased financial commitment are potentially world changing at a time when the world needs changing. The Stern report showed us that any hesitation in developing baseline, sustainable energy sources will require enormous spending when trying to recover in the middle of the century.

Scientific and technological research now shows that fusion is within reach if we are willing to pay for it. Fusion has, during its development, received a very limited budget given its potential to become the new, sustainable, base-load energy source. As an example, the Apollo project, with the task of placing a man on the moon, was given more money than what has been spent on fusion globally since the research started in the 1950's.

The fast track for developing fusion

Within thermonuclear fusion, a plan for development named 'fast track' has been designed. The first step is the construction of ITER and a material test plant. This is a worldwide collaboration. In ITER, the physics of a burning plasma and its resultant effects will be studied. The fusion demonstration reactor 'DEMO', which will provide electricity for the grid, is being designed for 2035, and after a few years, the commercialisation of fusion may then start. Construction of DEMO could be hastened if political decisions and budgetary limits were less strict; a major problem for fusion research in some European countries, like Sweden, is the freezing of budgets that have been prevalent for over a decade.

Sweden could contribute more

Swedish scientists play essential roles in both JET and the development of ITER. The JET project has been a huge success, achieving plasma temperatures and confinement that provide the understanding for defining the mission for ITER. The organisation of research units from different countries within the European Fusion Development Agreement has been very effective. Sweden's specialty

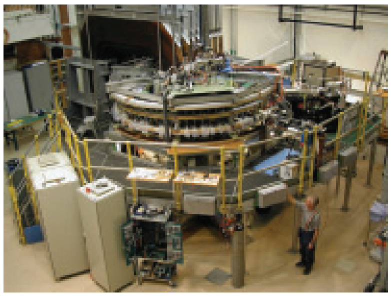

Fig. 3: The fusion experiment EXTRAP T2R at the Royal Institute of Technology, Stockholm, Sweden

fields are plasma control, plasma heating, plasma-wall interaction, neutron diagnostics, spectroscopy, and theoretical and numerical modelling of stability and transport.

Fusion has now left the stage of basic research to become an important part of energy R&D. It is thus time for the Swedish Energy Authority and agencies like VINNOVA to begin supporting Swedish fusion research and those industries that already have shown interest to take part in this exciting journey.

Climate warming urges immediate action

It is widely accepted by international science bodies, politicians and the public that we are all at a critical juncture in terms of industry and environment. The importance of fusion energy lies in its strong potential for clean and sustainable baseload power to compliment the maximum 50% capacity of renewables for Europe.

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