Energy for the Coming Generations; the Role of Fusion in the Future Energy Mix

A Dinner-Debate at the European Parliament

Members Salon,
European Parliament,
Brussels, January 25th, 2005

Dear Reader,

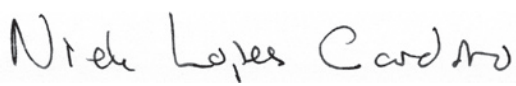
On the 25th of January 2005, Members of the European Parliament were invited for a dinner-debate on 'Energy for the coming generations; the role of fusion in the future energy mix'.

The dinner-debate, under sponsorship of Dr. Dorette Corbey, (MEP, PES) was attended by approximately 90 people, including 30 Members of the European Parliament or their assistents. Further participants included members of the European Commission responsible for research on energy issues, representatives of the Dutch government, the World Energy Council, the European Economic and Social Committee, and experts from European fusion research institutes.

The evening was opened by the Dutch MEP Dr. Dorette Corbey. Sir Chris Llewellyn-Smith, director of UKAEA-Fusion (UK), discussed the energy issue and the status and potential of fusion, followed by the Chinese perspective on energy and fusion by Prof Jiangang Li, director of the Institute of Plasma Physics, Chinese Academy of Sciences. Dr. Dorette Corbey closed the evening by phrasing questions and some political conclusions.

We felt that the collection of the speeches, augmented by additional information pertinent to the questions that were raised would make a useful document.

It is my pleasure to offer you this collection and I sincerely hope that you will find this booklet and the information contained in it of value.



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"Ladies and Gentlemen,

It is a great pleasure to see you all here in the European Parliament in such great numbers. It shows that the Fusion Road Show may be the best show in town tonight. I am honoured to say a few words of welcome for what promises to be an interesting debate.

For me it is a great opportunity to learn more about fusion energy: about its development, about its advantages, about its problems, and most of all about its future. I thank the FOM-Institute of Plasma Physics – for their enthusiasm to present their views.

It is always difficult to kick start an evening in the company of so many experts, who know all the technical ins and outs of fusion energy. At best, I can throw in three political questions concerning fusion energy for our debate.

> "A united, international approach to look for solutions that can prevent international energy conflicts and further deterioration of our climate is needed."

First of all an important question for politicians and decision-makers is about the return on investment. Which results justify the continued use of public money for research and development of this new technology? And related to that, for how long can we continue financing this technology? Should we continue spending money on fusion or would it be better spent on the promotion of renewable energies, such as wind and solar power and energy efficiency measures? These are important policy questions in times where the economic and financial situation in Europe is causing various problems.

Secondly, what is being done or what can be done in order to ensure and improve spill-over effects from the research and development activities in the field of fusion energy? It is one thing to try to build fusion power stations, but what other steps can we take to use knowledge in an innovative way? This is a question that falls within the broader framework to make Europe the most competitive, sustainable, knowledge based economy by 2010, the so-called Lisbon agenda. It is not just a political agenda, but it involves the creativity of all Europeans to come up with new ideas, solutions and products to move towards a better, healthier, equal and cleaner society.

Thirdly, what can we do to maintain and strengthen global cooperation in the development of fusion energy? I think a global perspective is important on a technology that promises such great advantages to future energy supply. With their depletion global energy sources hold great potential for future international conflict. Also the major contribution of conventional energy sources to global climate change is something that affects us all. As the dimension of both these phenomena will continue to grow, a united, international approach to look for solutions that can prevent international energy conflicts and further deterioration of our climate is needed.

Questions are very easy to ask. I hope to hear different answers, new perspectives and inspiring ideas. I wish you an inspiring debate and I hope we can have some conclusions at the end of the evening."

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"Dear ladies and gentlemen,

You are addicted. You are addicted to energy. We are all addicted to energy. To get your daily dose of energy, you are willing to make sacrifices. Together, we pay the price. Environmental disasters caused by breaking super tankers, smouldering coal fields emitting incredibly bad fumes, huge areas of inhabited land scraped off for lignite production, or flooded to form artificial lakes, millions of people that spend their lives underground in mines, dangerous and unhealthy, tens of thousands of them dying in accidents every year, proliferation of nuclear weapons material, climate change, floods, global warming. Our energy systems are vulnerable spots cherished by terrorists. We wage wars over the control of energy supplies.

"You use 5 kW per person, continously. That is not too much, it is not too little, it is precisely what you need to live a comfortable life."

We are addicted to energy. To get our energy we are prepared to make incredible sacrifices, and we are so used to it we don't think about it as such. Today, our energy comes practically for free, but what a price we pay. These offers don't affect just us; they will deeply affect the quality of life of our children and theirs.

You use 5 kW per person, continuously. That is not too much, it is not too little, it is precisely what you need to live a comfortable life. North-Americans use two to three times more – what a waste. However, 4 billion people use only a fraction, a few percent, of our energy use. Their standard of living, their economies are developing fast. And energy is the driver of that development. To earn 50 Eurocents of Gross Domestic Product, a country needs 1 kWh of energy. China takes into operation a new power plant every 3 weeks.

The world energy consumption is rising fast because large parts of the world are in the process of increasing their standard of living. We shall have to supply that energy, one way or another. No, not one way or another. We have to supply the energy in a sustainable way. And today the only thing we can say is that that is an enormous challenge.

If by the end of this century all, one hundred percent, of the energy production in the presently rich countries is Carbon free: zero CO_2 emission; and if 50% of the energy production in the rest of the world is CO_2 free – and these are daunting challenges; Even then, the total CO_2 emission is much more than it is now. Whereas we all know that it should be less, not more than it is now. At least, if it is our goal to limit the CO_2 concentration in the atmosphere to the famous 550 ppm, and even that goal may not be good enough.

Ladies and gentlemen, the transition to clean and sustainable energy production is a huge challenge. It is a challenge for Europe, but the problem is truly global. It is a challenge now, but the time scale at which the problem grows to its full gigantic dimension is 50 to 100 years. I believe that any consistent energy policy should reflect these two dimensions: we must solve the energy problem for the world, in the coming century.

Tonight we have invited you here to discuss what fusion energy can contribute in this frame. We are fortunate to have presentations by eminent personalities with diverse backgrounds, who will approach the issue from different angles. We hope that this will create a basis for a real discussion of the energy issue and the role of fusion.

It is my honour to be your guide through this evening. And the first thing I should like to draw your attention to is right in front of you – let us concentrate on food first, and then listen to Sir Chris Llewellyn-Smith. I wish you a stimulating dinner and debate."

Prof. Sir Chris Llewellyn-Smith

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"Ladies and Gentleman,

Niek Lopes Cardozo has suggested that fusion could play an important role in meeting the energy challenge. I shall outline the potential of fusion and the current status of fusion development. I shall then return briefly to the energy challenge and give my own views of how it should be met, the role fusion could play, and what Europe can contribute.

Very briefly:

- Fusion powers the sun and stars. The Joint European Torus (JET), which is the world's leading fusion facility, has produced 16MW of fusion power and shown that fusion can be mastered on earth.
- The advantages of fusion power are that it will be environmentally responsible and intrinsically safe, the supplies of fuel are essentially limitless.

- The major disadvantage of fusion power is, of course, that it is not yet available, and will not be available as soon as we would like. I am reasonably confident that we could make a fusion power station, and it looks as if the cost of fusion power will be reasonable. But time is needed to further develop the technology in order to ensure that a fusion power station would be reliable and economical, and to test the materials that would be used in its construction in power station conditions.
- An orderly fusion development programme – properly organised and funded – could lead to a prototype fusion power station putting electricity into the grid within 30 years, with commercial fusion power following 10 years later.
- Europe leads the world in fusion development, and is well placed to maintain its leading role.

Let me amplify these points.

The fusion reaction of interest on earth involves deuterium (heavy hydrogen) and tritium (super heavy hydrogen). Two conditions must be satisfied to make it work. First, a gas of deuterium and tritium must be heated to over 100 million °C – ten times hotter than the centre of the sun. Second, the very hot gas must be kept away from the walls as contact with the walls would cool it down. This is not the time or place to explain how this is done. If you would like to see for yourselves, on behalf of the EFDA-JET Leader, I invite you to visit JET, where temperatures of 150 million °C are routinely achieved. Visiting JET is easy – it is about one hour away from Heathrow airport.

As I already said, JET has produced 16MW of fusion power, but it was necessary to supply 25MW to heat the gas. This does not sound too good – more energy in than out. But comparing results from JET with results from devices half the size of JET gives us great confidence that a device twice as big as JET would produce very much more power than would have to be supplied the heat the gas.

The International Tokamak Experimental Reactor (ITER) will be such a device. It will be twice the size of JET, and should produce over 500MW of fusion power – at least ten times the power needed to heat the gas. ITER is essential to test and integrate various technologies on the scale of a power station. It should confirm that it is possible to build a fusion power station.

However, as I have already said, before constructing a fusion power station, we will need to test the materials for years in fusion power station conditions in order to get it licensed and to ensure that it is reliable. This can only be done in a special device called the International Fusion Materials Irradiation Facility (IFMIF). ITER, which will cost some €5 billion, and IFMIF, which will cost slightly under €1 billion, are the key items on the critical path to fusion (the cost may sound a lot, but is very small on the scale of the world energy market – which is €3 trillion pa). We all very much hope that construction of ITER will be approved in the very near future, and that construction of IFMIF by an international partnership involving the EU, Japan and others, will also be approved soon.

ITER and IFMIF will be followed by a prototype fusion power station, which could be putting electricity into the grid within 30 years if ITER and IFMIF construction begin relatively soon.

I shall now turn to the advantages of fusion, which I advertised earlier.

The raw fuels – from which deuterium and tritium are extracted and generated – are water and lithium, which is an abundant metal. All of you carry lithium around with you: it is a component of batteries of mobile phones and laptops. If used to fuel a fusion power station, the lithium in one laptop battery, complemented by half a bath of water, would – allowing for inefficiencies – produce the same amount of electricity as burning 40 tonnes of coal. 200,000 kWhrs to be precise, which is equal to the current per capita electricity production in my country (the UK) for 30 years

The fact that the lithium in one laptop battery together with half a bath of water could be used to produce so much electricity is sufficient reason to make every effort to develop fusion. Another excellent reason is that fusion produces no CO_2 or air pollution – indeed the so-called 'external cost' of fusion power (damage to health and the environment) will be close to zero.

> "An properly organised and funded fusion development programme could lead to a prototype fusion power station putting electricity into the grid within 30 years, with commercial fusion power following 10 years later."

What about safety? A key fact is that, although it will occupy a large volume – 1,000m^3 or more, the amount of tritium and deuterium in a fusion reactor will be tiny: the weight of the hot fuel in the core would be about the same as ten postage stamps. Furthermore, there is not enough energy inside the plant to drive a major accident and not much fuel to be released to the atmosphere if an accident did occur.

What are the hazards? First, although the products of fusion (helium and neutrons) are not radioactive, the walls of a fusion reactor will become activated when struck by the neutrons. However, the radioactivity decays away with half-lives of order 10 years, and all the components could be recycled within 100 years. Should the cooling circuit fail completely, radioactivity in the walls would continue to generate heat, but the temperature would peak below 1200 °C and melting would be impossible.

“Europe leads the world in fusion development. The programme is fully integrated on the European level.”

Second, tritium is radioactive, but again the decay half-life is relatively short (12 years) and the hazard is not huge. In any case it would be easy to design a reactor so that even in the worst imaginable accidents or incidents (such as earthquakes or aircraft crashes) only a small percentage of the tritium inventory would be released and evacuation of the neighbouring population would not be necessary.

The recent European Fusion Power Plant Conceptual Study has confirmed the environmental advantages of fusion and has also shown that the cost of fusion power will probably be reasonable (especially if external costs – damage to health and the environment - are taken into account).

How will fusion contribute to meeting the energy challenge? The challenge is a consequence of the facts that

- energy use is expected to double in 40 years, and an even larger increase, differently distributed, is needed to lift the world out of poverty, but
- 80% of the world’s energy is generated by burning fossil fuels which is driving climate change and generating debilitating pollution, while in any case, fossil fuels will eventually be exhausted – the first sign will be a decrease in the rate at which oil can be produced, which could occur relatively soon.

There is no ‘magic bullet’ that will solve the problem. The response must be a cocktail of measures: we must increase energy efficiency, deploy wind power wherever sensible, etc. Indeed, we must invest in developing and deploying a wide range of technologies. This range must include the few technologies that are capable individually of making a major impact. I am only aware of only four such technologies. One is old – it is nuclear fission, which I do not intend to discuss tonight. The new technologies are: carbon capture and sequestration – which would make burning fossil fuels more acceptable if it can be done safely and economically; solar power – but it is currently far too expensive and supply is not well matched to demand temporally or geographically; and fusion.

All experts agree that (in the words of the International Energy Agency) "achieving a truly sustainable energy system will call for radical breakthroughs that will alter how we produce and use energy". But government funded energy R&D has dropped 40% in real terms, world-wide and in the EU, since 1980. It is currently only 0.3% of the €3 trillion pa energy market R&D. A large increase in R&D funding is imperatively needed, and some of the increase should be directed to fusion.

As I said earlier, Europe leads the world in fusion development. JET is currently the world's leading fusion research facility, and we have a number of other world class facilities with unique features. The programme is fully integrated at the European level, and funded jointly by the European Commission and the Euratom member states. The decision of the Council of Ministers to host ITER at Cadarache in France will ensure that Europe retains its leading role.

Europe needs to maintain a vigorous fusion programme in parallel with the construction ITER. The goals of this programme will be: to ensure the early success of ITER, to prepare for the rapid construction of a prototype fusion power station following ITER, and the subsequent commercialisation of fusion power, and to position European industry to play a key role in a future fusion power industry. I hope that we will have your support in obtaining the funding needed to carry out this programme.

“I am absolutely certain that with so few options available we cannot afford *not* to develop fusion as fast as possible. We must do it and I would like to see Europe continuing to lead the development of fusion.”

In conclusion, I would be amazed if the world is not using fusion power 100 years from now. If fusion development is properly organised and funded, commercial fusion power could be available in 40 years. I am not certain of this date – it assumes adequate funding and appropriate organisation of fusion development, and that there are no major surprises. I am, however, absolutely certain that with so few options available we cannot afford *not* to develop fusion as fast as possible. We must do it and I would like to see Europe continuing to lead the development of fusion.

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"Good evening, ladies and gentlemen.

I would like to thank Dr. Dorette Corbey and Dr. Niek Lopes Cardozo for inviting me to this diner debate. It is a great honour for me to be here to share with you my view on this important issue: energy, both as a fusion scientist and as a home team leader of China ITER. Here, sitting in this warm, brightly-lit hall, I find myself more propelled to talk about the energy situation in China than at any other time.

In my childhood, I was taught in our geography lessons that China, with its huge area, has a wealth of resources. Now we come to know that any huge reserve becomes little when divided by 1.3 billion people, while any trivial problem turns out to be huge when multiplied by 1.3 billion.

> “If China grows up to be a moderately developed country in 2050, the annual energy consumption per person will increase three times.”

China’s resources are poorly balanced. We take up 11% of world coal, 13% hydropower, but only 2.5% oil, and 1.2% gas on earth. This determines the energy status in China. That is, our energy consumption structure is based on coal, nearly 70%, and we had to import 40% oil last year, becoming the world’s second largest oil importer. At the same time, China suffers from poor efficiency in turning oil and coal into economic output – just 1/7th that of Japan.

China’s economy has sustained 7-9 % annual growth for the past 20 years, with a spectacular 9% in 2004. If China grows up to be a moderately developed country in 2050, the annual energy consumption per person will increase three times, from the current 1 TCE to more than 3 TCE, (at the present time, US: 11.5 TCE; Western Europe: 5.6 TCE; Japan: 5.1 TCE). The estimated energy demand will increase four times, from 1 billion TCE now to over 4 billion TCE in 2050, and to make things worse, the Chinese population will inevitably grow from the present 1.3 billion to 1.6 billion by then.

It is a disturbing picture that our coal-centred energy structure already now is causing many problems, such as pollution and global warming, while there are also problems with safety, sustainability and, because 83% of the coal reserves are located in the North-Western part of China, with transportation.

China is the second largest CO_2 producing country. If its energy structure can not be changed, the CO_2-emission will increase by a factor of two within the next 20 years. This will certainly have a big impact on the global environment. Moreover, coal and oil, this non-reproducible fossil fuel, will not meet our energy demand for long-term sustainable development.

China's growing reliance on imported oil, pollution and looming water shortages pose the major threats to its economic development. However, a change of the energy structure needs a very long time. It would take 50 years and tremendous efforts to reduce the contribution of coal to 50% in the Chinese energy structure, and 100 years to bring the number down to 24%, the present world average level.

The energy problem is bound to get more serious if we don't take it seriously now. Well, what and where are the answers? The answer is to improve the energy efficiency and explore new clean energy sources.

To realize the long-term sustainable development, it is necessary for China to exploit renewable energy and operate thousands of GW non-fossil fuel power plants.

We have many solar-power and hydrogen programs, unfortunately on a small scale. Hydropower, although developed quickly during the past five years, accounts for only less than 10% of the total energy consumption. Fission reactors will be emphasized within the next 15 years. 20 fission power plants of 1 GW will be built in China (There are 6 nuclear plants, for a total of 8.7 GW, now), only to generate about 4% of electricity needed, hardly making a dent in the ultimate solution. However, to build hundreds of GW Fission Nuclear Power Plants in China, social problems, safety and environmental concerns, and technical difficulties would have to be tackled beforehand.

It seems at present that we, humankind, do not have many choices in energy. To our delight and relief, fusion is at hand. Fusion has been proved to be a potential source of secure, inexhaustible and environmental friendly energy, as mentioned by Chris Llewellyn-Smith. It is the far-sightedness and sagaciousness of state governments in the European Union to earmark large funds to support fusion research, and it is innovative and bold of you to spearhead and push forward the ITER program.

Now, EU leads the world fusion research. The world largest experimental reactor, JET, located in UK, is the result of joint efforts from EU partners. It set up a very good example for international cooperation. Significant results have been achieved both in the science and management. The record for long hot plasma duration was obtained in the superconducting tokamak Tore-Supra, in France. The EU also has a very strong technical base for fusion technology. The so-called Fast-Track, proposed by Sir. David King, is a very attractive plan to speed up the fusion energy development. We hope the "Fast-Track" could be faster.

For China, the largest developing country on the earth, fusion energy is especially important for its long-term sustainable development. We need fusion energy more urgently than any other country.

Chinese Fusion Research started 30 years ago. Even though it is relatively small, it has developed steadily and gathered a faster pace during the past five years thanks to the strong support from the government. The HL-2A tokamak experiment, modified from the old German tokamak ASDEX started operation in 2003. The EAST tokamak, the world's first fully superconducting tokamak, will be operating at the end of this year. We need a tokamak test-reactor, like ITER, within 20 years.

It is beyond our financial ability and technological know-how for China to build an ITER-like machine at the moment. By joining ITER, we can share the knowledge involved in ITER and take a more aggressive step, saving both R&D time and budget, promoting the domestic fusion related industries and training young scientists and engineers. China believes that ITER can potentially lead to a new form of energy and contribute to the peaceful and sustainable development of the world in the long run.

> "For China, the largest developing country on earth, fusion energy is especially important for its long-term sustainable development."

A wide discussion about joining ITER has been carried out in the Chinese science communities and different ministries. The central government made a very quick decision after getting the proposal from the Ministry of Science and Technology. China expressed its strong commitment in becoming a valuable member of the ITER family, to make joint efforts with other partners to the successful exploitation of fusion energy.

The ITER International Team headed by Dr. Aymar made a two-week trip to China to check the capacity of Chinese fusion research. Their conclusion was: "Equipment and methods in use in the laboratories and industries visited were similar to those in the more developed countries. In particular, QA programmes were implemented, in a manner that already satisfies their European and Japanese customers. It was clear that the Chinese would be able to make an in-kind contribution of satisfactory quality to ITER construction."

After joining the ITER negotiation, China has been making significant efforts for the ITER. Twelve tasks have started in China, two of them have been finished. Nearly 100 scientists, engineers and graduate students are working on ITER tasks. Fusion energy research has been listed in the national long-term strategic development blueprint, and the fusion budget will probably be increased by a factor of three within the next 15 years. Chinese decision-makers have come to believe that fusion is one of the very few options for large-scale sustainable energy

“China is committed to work together with the ITER partners to build ITER at Cadarache.”

generation and therefore must be developed as quickly as possible.

The ever-shining sun generates inexhaustible power by fusion, ensuring us that we can emulate the sun. Indeed, fusion is the gift from God to humankind. For decades, the world fusion community has pooled together their intelligence, passion, enthusiasm, efforts and friendship in search for this inexhaustible energy and its peaceful use in future. This is beneficial to us all and the EU has set up a good example in their fusion programs. We Chinese scientists and engineers would like to work closely with the ITER partners to build ITER at Cadarache, since it has many technical advantages to ensure ITER to be built safely and quickly.

“Fusion has always been 50 years away, – and always will be”, as the old joke goes. If fusion is a dream, and it has been dreamt for generations, never has this dream been this clear and this realistic as today in the ITER program. We sincerely hope the deadlock in the ITER site decision can be solved quickly and that the construction can start as soon as possible.

Energy is a global problem, as it is central to economic development, climate and environment, and international stability and sustainability. The change of the world energy structure needs 50-100 years. Fusion is one of the very few options for large-scale sustainable energy generation and therefore must be developed as quickly as possible. China needs fusion more urgently than any other country and would like to be one of the first users of fusion energy. The EU has acquired a very strong position in fusion research at the moment and should make continuous efforts in leading the realization of the fusion energy in the future. China is committed to work together with the ITER partners to build ITER at Cadarache.”

Concluding Remarks

Dr. Dorette Corbey

"1. A lively and interesting evening.
It was a pleasure to listen to committed speakers and also to learn about fusion. The friendly atmosphere was appreciated. Thanks to all MEPs that are present for their interest, special thanks to speakers for their introductions and again thanks to the organisation for its commitment to bring fusion into the parliament.

2. Fusion shows many advantages...
The list of advantages is impressive: fusion energy is cheap, safe, clean and efficient. Moreover future reactors will be earthquake proof and resistant against terrorist attacks. It was said to be safer to live next door to a fusion reactor than to a coal power station. Fusion is the solution to energy shortage problem, a problem that cannot be solved by sun and wind power. The only disadvantage of fusion technology is, is that is it is not there yet. Worse, it will take 50 years before commercial exploitation is possible.

3. Fusion R&D is costly...
Political commitment is needed to continue to pay large amounts of money to fusion, although much more subsidies are paid to fossil fuel sectors. In general it is difficult to devote public money to something that will pay off only 50 years later. Three problems were mentioned:

First: it is not clear why costs are so high - or how they compare to R&D costs to other energy sources.

Second, it is hard to understand why it takes 50 years to commercialize fusion power and why the process cannot be speeded up significantly, even if more money is spend.

Third, the spin-off is there, but not quantified, nor specified. Fusion research and its spin off can be a booster in the Lisbon process - but clarity is needed for that.

Answers to these points would ease the political debate. Political choices are more easy to make if there is a reasonable certainty that investments will pay off and that investments will pay off X years sooner if Y euros more are available.

4. China is committed to fusion

It was interesting to learn about the continuing commitment of China. There is a huge and growing demand for energy in China. There is also a growing concern about the environmental backlash (air quality, climate). The Chinese authorities see fusion as the future source of energy. China's commitment may be an important incentive for the EU to continue, to renew or to enhance its contribution to fusion power."

1 What are the spin-offs of fusion research?

(note by Sir Chris Llewellyn Smith)

Fusion Research and Development is focused on producing an economically viable, environmentally responsible, safe source of energy. If the programme is successful, fusion itself will be much more valuable than any spin-offs: the world energy market is about €3 trillion per year. Fusion spin-offs should nevertheless be fostered and the benefits of contracts maximised, taking care that this is not at the expense of the main mission of fusion R&D. Some industrial involvement (including funding) is already partly motivated by the potential fusion power market, for example in South Korea.

During the development of fusion power, many of the leading-edge technologies involved have been pushed to new limits, leading in many cases to innovative solutions that have found applications beyond the bounds of fusion. A recent brochure[1] describes some of the numerous spin-offs and knowledge transfers that have resulted from close collaboration between the European Fusion Associations and industry. They span many areas, including: remote handling systems, semiconductor manufacturing, large area plasma etching and deposition, high heat-load components and materials, extreme ultraviolet (EUV) lithography (needed to produce next generation computer chips), precision extreme ultraviolet (EUV) optical elements and masks, ion implantation and plasma High Definition (HD) TV display panels. As 80% of the costs of ITER will go to industry, ITER promises a wealth of additional spin-off opportunities for those involved.

The range of examples of spin-offs from fusion research are similar to those from high-energy particle physics. This is not surprising as many of the technologies involved are the same. A study of high-tech contracts placed by CERN[2,3] and the European Space Agency (ESA)[4,5] found that they had an average 'economic utility' (= increased turnover plus cost savings, not profit) equal to three times the value of the original contract. Of the CERN-related sales increases, 75% were in areas unrelated to particle and nuclear physics - solar energy, electrical industry, railways, computers, and telecommunications.

CERN staff also reported benefits from working with industry. In general, learning and innovation go together. The greater the involvement (trust, access, personal relationships, etc.) the greater the mutual benefit. Experience in particle physics[6] and fusion has shown that partnerships are more fruitful than conventional procurement. Hands-off hi-tech contracts frequently lead to problems. Industry needs to be involved early on in R&D for hi-tech projects that will generate significant contracts.

Apart from the production of large scale electricity, fusion technology can be used for a number of other purposes, both near-term and long-term. A recent report[7] discusses the following examples: the production of inexpensive Positron Emission Tomography (PET) isotopes for medical diagnosis, the detection of clandestine materials such as explosives (for example, landmines), transmutation of spent nuclear fuel, hydrogen production and space propulsion.

1) *Fusion Energy, Moving Forward. Spin-off benefits from Fusion R&D*, European Commission, EUR 20229, 2003

2) *A Study of Economic Utility resulting from CERN contracts*, H. Schmeid, CERN Yellow Report, CERN 75-5 (French), 1975 and IEEE Trans. Eng. Mgt., EM 24, no 4, p. 125, 1977

3) *Economic Utility resulting from CERN Contracts (Second Utility)*, M. Bianchi-Streit et al., CERN Yellow Report, CERN 84/14, 1984 and Quantification of CERN`s Economic Spin-off, Czech. Journal of Physics, B38, p. 23, 1988.

4) *Les effets économiques induits de l`ESA*, P. Brendle et al., ESA Contracts Report, Vol. 3, 1984.

5) *Study of the Economic Effects of European Space Expenditure*, L. Bach et al., ESA Contract No. 7062/87/F/RD/(SC), 1988.

6) *Technology Transfer and Technological Learning through CERN`s Procurement Activity*, E. Autio et al., CERN Yellow Report, CERN-2003-005, 2003.

7) *Nonelectric Applications of Fusion*, K. McCarthy et al., Journal of Fusion Energy, Vol. 21, no. 3/4, p.121, Dec 2002

2 Can fusion research go faster?

(note by Sir Chris Llewellyn Smith)

In the last decade there has been great progress in the plasma physics, materials science and technology of fusion power. All these subjects have reached the stage where the remaining development requirements can be readily envisaged, and the main research facilities and activities planned. This progress has led to a clear path to the realisation of economic and environmentally attractive electrical power generation: the main technological requirements are known, and approaches to the resolution of the principal issues have been evolved and broadly accepted.

In 2001, the Research Council charged a group of independent experts chaired by Sir David King, scientific advisor to Tony Blair, to investigate fast routes for fusion to deliver electricity to the grid. The King-group developed the so-called “Fast Track” development scheme for fusion power[1], which aims at one or more electricity generating prototype power plants (DEMO’s), within 30 years after the decision to go ahead with ITER. These power plants will be connected to the grid, and can be directly followed by the construction of commercial fusion power plants.

In recent years, the Fast Track scenario has received widespread acceptance, and has been developed in further detail[2]. The American fusion advisory committee FESAC, in a report to the US department of energy DOE, follows the same time path[3]. The Fast Track substantially reduces the total costs to reach the long-term goal, for the price of increased short-term funding. Choosing this path is an essential first step towards speeding up the development of fusion energy.

In terms of major facilities, the essential next stage in the fast track development of fusion is the parallel construction and exploitation of the ITER tokamak and the International Fusion Materials Irradiation Facility (IFMIF), before the construction of the first electricity-producing DEMO plants. Commercial plants would directly follow the DEMO step.

In addition to the facilities so far mentioned, the continuation of a number of existing devices and the utilisation of possible future ancillary devices and projects is a necessity. This supporting programme reduces the overall risk, extends the available options, and is essential for training scientific staff.

The fast track – as its stands – is a conservative and careful approach with an emphasis on gaining sufficient knowledge at each step before proceeding. However, increasing the funding and/or introducing risks in the fast track project plan could result in DEMO providing electricity into the grid more rapidly. In evaluating the fast track, consideration has been given to an accelerated programme by construction of additional satellite tokamaks to support and shorten the ITER programme, testing of some powerplant materials before IFMIF operation and testing of in-vessel components before DEMO using a dedicated Component Test Facility. In addition, the parallel operation of more than one IFMIF and/or more than one DEMO would further reduce the timescale whilst also reducing risks and expanding options. So, could the fast track be any faster? The answer is yes – with increased funding and/or the introduction of a less conservative programme of activities.

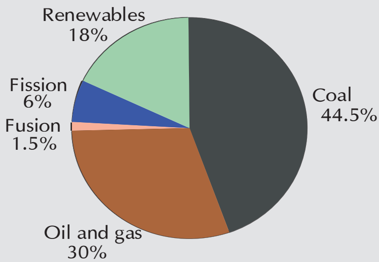
1 *Conclusions of the fusion fast track experts meeting held on 27 November 2001 on the initiative of Mr. De Donnea, president of the research council,* EUR (02) CCE-FU/FTC 10/4.1.1, Brussels, 5 Dec. 2001 (commonly called the "King Report")

2 *Accelerated development of fusion power,* I. Cook et al., UKAEA-Fusion, Feb. 2005

3 *A plan for the development of fusion energy,* DOE/SC-0074 (FESAC report), March 2003

3 How do the costs of fusion research compare to other energy costs?

The present worldwide budget for fusion research is about 900 million euro per year. As fusion research has the goal to produce a large scale source of sustainable energy that can satisfy a significant fraction of the global energy needs, this should be compared to, for example, the combined exploration budgets of the oil companies, or the total energy market. For instance, the worldwide electricity market is about €1 trillion a year, and the world energy market is about €3 trillion a year. So, any energy source that can impact the energy market, even at a few percent, has got a market of tens of billions of Euros per year.



Energy subsidies and R&D in Europe. Total: 30 billion Euro. Source: EEA, EU-FP6 programme

The European energy bill amounts to €700 billion a year. In energy subsidies and R&D, Europe spends €30 billion annually. The European Union and national governments spend 450 million a year on fusion research, which amounts to 0.06% of the total energy bill and 1.5% of the total budget for energy support. The distribution of funding for energy research and energy subsidies is shown in the figure.

Fusion on the web:

www.fusion.org.uk
Website of the Euratom/UKAEA Fusion Association, at the Culham Science Centre, UK.

www.efda.org
Website of the European Fusion Development Agreement

www.iter.org
Website of the international ITER-project

www.jet.efda.org
Website of the Joint European Torus (JET), the world's largest fusion research facility, and the focus of European fusion research.