Fusion Industry Innovation Forum (FIIF)

Industry Comments and Recommendations on the EU fusion programme

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1. INTRODUCTION

In line with EU energy policy, the SET-Plan and Innovation Union objectives the mission of the FIIF is threefold.

Firstly, working in close collaboration with the research programme, industry will contribute to the development of fusion technology and the design and construction of a prototype fusion power plant. This will be realised by jointly, research centres and industry, defining programmatic, industrialised and technological power plant road maps with clear milestones and resource estimates coupled to a realistic time frame. These road maps will give fusion research especially industry, a long term vision of fusion development providing continuity to their fusion activities and allowing them to develop the necessary skills and competences, thereby creating the basis of a European fusion industry.

Secondly, from a comprehensive fusion power plant technology development programme and the construction of ITER with technology transfer between research centres and industry, the conditions for innovation in various technologies with secondary applications outside fusion will be fostered and strengthened. Industries, both large and small, that recognise technologies which complement their current or future business plans, will, through the forum and the Euratom IPR framework, have the opportunity to exploit the knowledge generating competitiveness, jobs and economic growth through spin offs, new products and services to market, and technology and production development in industry.

Thirdly, the forum will prepare and promote a programme for the development of all the required industrial and regulatory skills and competences of organisations and individuals to place European industry and the European energy market at the forefront of any future fusion power plant commercialisation and derived innovations.

As a first delivery on this mission, the FIIF Management board has performed a review of the programme in each of the three main objectives and can provide the conclusions and recommendation presented in the following three sections. Elements of this work could be considered for the Commission proposals on the Common Strategic Framework.

2. OBJECTIVE 1: TECHNOLOGY ROAD MAP TO A FUSION POWER PLANT

ITER is now well established and is expected to complete construction in 2019 with an important milestone of testing the tritium breeding systems in 2026. With the successful completion of this mile stone fusion research will have reached the stage to be able to launch the construction of the demonstration electricity generating power plant. This future power plant will be the first opportunity for the regulators, utilities and supply industry to understand the economic, social, and environmental potential of such a technology. To be able to realise this decision point within the schedule presented in the SETPlan, i.e. demonstration of electricity from fusion by 2040, it is necessary to perform significant preparatory work prior to 2026, with the launch of conceptual design activities followed by a detailed engineering design.

The Euratom undertaking responsible for the European supply to ITER, Fusion for Energy in Barcelona, is also tasked with the development of the Demonstration Fusion power plant (DEMO), but in the period 2011 to 2019 the organisation is solely dedicated to the construction of the ITER project. It has been decided, therefore, that the conceptual design activities will be performed within the general research programme and upon reaching a certain level of maturity will be transferred to Fusion for Energy to complete the detailed engineering design. In the EFDA organisation a department for Power Plant Physics and Technology has been formed with the responsibility of coordinating the pre-conceptual and conceptual design activities. The Euratom FP7+2 will complete the pre-conceptual activities and the conceptual design phase will be launched at the start of the next Common Strategic Framework (CSF) (during 2014).

The conceptual design of an electricity generating fusion power plant is a first step from science to application in fusion research. It is therefore important that at an early stage all stakeholders (regulators, utilities, supply industry, political leaders) are involved and jointly develop and agree the design with the provision of the necessary tools and support.

The Fusion Industry Innovation Forum (FIIF) has been formed to contribute to the development of fusion technology and the design and construction of a prototype fusion power plant in line with the programme requirements stated above. The first step in this

process is for the forum to work closely with the fusion research community to assess the state of the art of the power plant activities and to reach a common understanding with the research programme on the most practical way forward with recommendations to the programme on its implementation in the near and long term.

After an intensive meeting on the 10th and 11th of May between the forum and the research community, the forum has agreed that the goal for a future Power plant should be:

"to generate significant amounts of electricity (=1GWe) to the grid in the earliest realistic time frame, balancing risk and cost but demonstrating workable efficiency and availability with an operational time of at least 10 years"

From this initial review of the present technologies available and the current understanding of the physics, the main challenge is the development of the materials and the power extraction concepts for the divertor which will require a focussed effort in both physics and technology. Current technology can be used for the remainder of the plant although progress must be made to improve the heating efficiencies in order to minimise the recycled power. High temperature superconducting technology should also be investigated as this would drive simplification of the magnet system. Development of these technologies must be an important part of the future fusion research programme.

Concerning any future conceptual design, the forum recognises the complexity and interrelationship of the main tokamak systems especially the remote maintenance aspects which will drive the availability of the plant. In addition to the design and integration of the internal components, the complete balance of plant and systems integration is a very important aspect and should also be addressed. In this aspect industry has all the capabilities to offer to the programme and integrating industry into the design activities would provide industry with a full understanding of the issues involved as well as bringing to the design a complete systems integration providing a sound foundation on which to proceed with the detailed engineering design activities.

Based on this initial interaction with the programme on a technology road map to a power plant, the forum can recommend the following:

- *The most important requirement of the next generation tokamak after ITER is to demonstrate the generation of a significant (several hundred mega watts) amount of electricity to the grid as well as the autonomous operation of the closed fuel*

cycle. The real economics of fusion power can be assessed at a later stage when there is a better understanding of the energy mix and pricing of the day.

- *A long pulsed (several hours) tokamak would be acceptable as a demonstration power plant.*
- *The fusion programme should give priority to providing design solutions for essential elements of the tokamak internal components e.g. power extraction systems, materials, etc..*
- *Availability of the plant is one of the most important requirements for an operator and in fusion will be driven by the remote maintenance. Development and integration of remote maintenance concepts should become a leading requirement of the design*
- *Any conceptual design activity should include a strong systems integration and management, incorporating all systems and processes.*
- *Regulators and utilities should be integrated into the conceptual design process.*
- *To build a future fusion industry in Europe the programme should provide tools that would integrate industry in the design and systems studies at the start of the design process.*

The forum will continue to work with the research community in the detailing of a technology road map to a power plant and more details will be provided in further reports.

3. OBJECTIVE 2: A PROACTIVE TECHNOLOGY TRANSFER PROGRAMME AND KNOWLEDGE MANAGEMENT

Attainment of the goal of fusion power is an exciting and stimulating challenge. Along the way many of the leading-edge technologies involved will be pushed to new limits and in many cases the innovative solutions to the challenging problems will find applications far beyond the bounds of fusion.

Due to the expected long time-to-maturity of the development of the fusion power plant technologies and the related systems know-how, an early capitalization of the results of fusion energy research and development needs to focus on spin-offs to other domains than

fusion energy. This already occurs at a national level but could be expanded and become more visible if a coordinated European approach is taken. Only in a somewhat later stage the know-how transfer to potential prime contractors of commercial fusion power plants and service providers would become relevant

Accordingly, a technology transfer roadmap shall comprise both near and long term activities:

1. a phase focusing on the identification of spin-off opportunities and the corresponding technology transfer to SMEs and other interested entities
2. and a phase fostering the transfer of technology and systems engineering know-how to potential power plant builders

The Forum has performed case studies of the technology transfer activities of CERN, KIT and ESA and consider that the general approach of these organizations should be considered in the fusion programme organized mainly through the establishment of a Technology Transfer Programme Office (TTPO) supported by the Community but also drawing on the many European and national funding opportunities available for technology transfer and spin-off generation. The mission for such a TTPO would be:

- Analyse processes, tools, best practices and lessons learnt of existing international transfer initiatives
- Contact national spin-off generation initiatives and repeat the a.m. step, as far as is possible
- Taking the results of the a.m. two steps into account, establish, both w.r.t. processes and tools, the details of an EU-driven Technology Transfer Programme such that the national initiatives are incorporated in a most efficient (win-win) way
- Contact potential technology brokerage companies and establish a Europe wide Technology Brokerage Network (TBN)
- Implement a Europe-wide accessible web-based Technology Marketplace
- seek entrepreneurs with innovative ideas for using fusion energy technology, applications and services in domains other than fusion energy

- Implement a Business acceleration Incubation Centre providing technological, financial and legal advice to start-up companies
- Implement a seed money funding scheme
- Enable technology transfer with existing knowledge in existing companies
- Once means and processes are established, supervise its proper operation, perform industrial information events and implement a continuous improvement programme w.r.t. the spin-off generation systems

The funding framework should take benefit of all the funding resources and bodies that the Fusion Program has access to in order to create a suitable amount of resources that will ensure a stable running and outstanding performance of the Technology Transfer Program. This should include funding from the CSA program, the CIP program, interested venture capitalist, corporate venture funds, and the returns of the Technology Transfer program itself.

Once the feasibility of exploitation of fusion energy has been adequately assessed through the successful mission of ITER and an advanced stage in the detailed design of a demonstration electricity generating fusion power plant, specific technologies including know-how concerning the overall system engineering, the system design for remote handling, RAMS- and FDIR, the design and manufacturing of subsystems and equipment, and the transfer of know-how w.r.t. operational processes should be transferred from research to power plant industry, both primes and subcontractors.

This implies capturing

- the complete spectrum of knowledge generated from ITER and other demonstrators that is required by industry to build fusion power plants
- in a format suitable for its transfer into industrial processes

More specifically this means that a knowledge management process should be initiated, coordinated and managed by the TTPO using project management orientated tools to guarantee the maximum knowledge return and storage from ITER and other projects.

Based on the above analysis and conclusions the Forum can make the following recommendations for the near and long term fusion technology transfer actions:

Near term

- *Launch a pilot project (Coordination and support action with minimum of 3 years duration) to set up the organisation and management requirements for a EU Fusion TTPO that will enable and incentivise technology transfer from the fusion programme to industry and to the market. This pilot project should have the following deliverables:*
    - *Provide three TT success stories from fusion IPR assets*
    - *Provide a web based fusion technology market place;*
    - *Provide a best practice guide to technology transfer and spin off generation*
    - *Provide the necessary infrastructure for effective and efficient TT and Spin off (e.g. technology broker network, incubator network, funding network, legal framework)*

Long term:

The output from the pilot project should then be embedded in the instrument that will provide the basis for the fusion power plant conceptual design activities managing:

- *The Professional technology transfer from ITER with complete documentation management and transfer provided for industry involved in Power Plant activities*
- *Technology Transfer and spin off from the fusion Power Plant design and development activities to all industry*
- *Technology Transfer and spin off generation from the general fusion research programme to all industry*

Annual Indicators for the performance of the TTPO should be: Number of marketable technologies and possible application field, number of patents/copyright/knowhow licensed, number of successful agreements, no of spin-offs created, return on investment.

4. OBJECTIVE 3: PREPARING A FUSION INDUSTRY FOR THE FUTURE

Skills development in all fields is an important and long term activity and necessary for a sustainable economic and competitive economy. Present day fusion research is practically

100% publically funded and human resource management concerns mainly the development of highly skilled scientists and engineers in the research centres to maintain the knowledge in fusion science and technology, which due to it specific nature is multi generational.

The fusion power plant after ITER will be the first step from science to application requiring industry integration into the design and construction of such a power plant to prepare a future fusion industry. For this it is necessary to develop the required industrial skilled. Examples for the growth of an industry can be taken from the NASA space programme or more specifically the deployment of the nuclear fission industry in the 1950's. In the latter case industry, regulators and leaders were required to put in place infrastructures and legislation for a completely new, technically demanding technology. Most importantly a completely new generation of engineers required to be educated and trained to design, build, operate, and regulate the nuclear power industry. To realise the demonstration fusion power plant much of this infrastructure can be used and adapted, but a significant industrial training programme is required if European industry is to become a leader in fusion power exploitation.

The Fusion Industry Innovation Forum was formed to provide recommendations on the industrial training needs in fusion and recommend suitable instruments to address such needs. For the transformation from science to application, the training will be implemented in a gradual way with, at the start, low volume, but highly directed actions to gradually larger volume and more general training as the maturity of the technology develops and industry starts to take the lead and commercialise the technology. The forum has made a review these needs for a future power plant programme, by looking at existing actions and through a pole of industry.

Existing education and training mainly focuses on basic education with almost no training directed towards professional engineers in fusion related industrial activities. Education and training actions are not job driven in most cases with the content mainly dealing with fundamental issues. Plant design, construction and operation are considered only in some exceptional cases. Actions exist, such as the GOT and Career Development Fellowship programme under EFDA, but these are restricted to the participation of public research centres. They were created to foster scientific excellence in the programme and balance the proportion of engineers and physicists as well as cope with the demand to staff the

ITER project team. The Commission also launched a coordination and support action "FUSENET" that creates links between the research centres and universities expanding the supply of future fusion researchers.

In the area of Nuclear fission, a number of "*Euratom Fission Training Schemes"* (EFTS) have already been launched in specific areas where a shortage of skilled professionals has been identified. This programme operates in a similar way to the fusion GOT training scheme.

Future education and training initiatives will have to be based on training needs of all stakeholders in nuclear fusion, i.e. not only research centres, but also utilities, other operating organizations, suppliers, regulators, TSOs, decision makers in politics and in industry.

From the survey of industry, in many cases, no competence was reported in the area of civil design, nuclear licensing, and nuclear grade qualification and control. Experiences were available mainly in engineering support, quality assurance and project management, diagnostics, electrical power supplies and material development. In many cases, the job positions of system engineers, process engineers and procurement engineers did not exist. In contrast, the following job positions were rated as important for future fusion activities in the respective companies: system engineer, instrumentation and control engineer, electrical engineer, mechanical engineer, quality management engineer, interface and configuration management, project engineer, procurement engineer, project manager, and engineering manager. Nearly all agreed that a professional training passport recognized e.g. EU wide, will be advantageous.

The survey performed already indicates that current initiatives insufficiently satisfy the emerging training requirements. Therefore future focus must be on application of traditional technical (e.g. system, process …) or other (management, procurement, quality assurance …) disciplines in fusion related activities.

In the near term it is necessary to adapt the existing competence of the present work force to fusion application needs. Consequently, different training schemes will have to be designed, developed and implemented to satisfy these needs. Based on the analysis presented in this report the forum has the following recommendations:

- *Develop and implement a pilot scheme for training professional engineers in the disciplines highlighted above using the principles set out in the EFTS (fusion) and EFTS (fission) initiatives under the umbrella of*

ENEN[1]*. These training schemes shall include dedicated fusion courses provided by the fusion community, but also practical training performed by internships and on-the-job training. Development and implementation of the pilot scheme should also allow for creating recognisable centres of excellence for academic and vocational training in the different needs of the future fusion industry.*

- *In parallel, establish a pilot European Master of Nuclear Engineering / Fusion under the umbrella of ENEN, therefore fostering the international cooperation of different education and training institutions.*
- *Embed training actions in the power plant conceptual design activities including training on prototype and demonstration projects as well as systems integration, interface and configuration management, thereby taking full benefit from the ITER projects and existing facilities.*
- *Involve experienced personnel from professional training institutions, dedicated to the design, development, coordination and implementation of training actions for all stakeholders in fusion research.*
- *Include basic industry related job positions in the FUSENET mission and feed the initiative with industry needs in education and training, specified by the FIIF.*
- *Contribute to a European Skills Passport, supporting the current European Commission's initiatives.*

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[1] www.enen-assoc.org

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