IFERC Newsletter

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DEMO Design Activity

An attempt to realistically Map the Road to Fusion Electricity

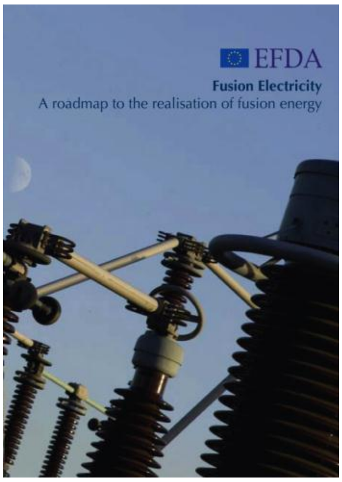
The realisation of fusion energy has been significantly advanced by the decision to build ITER. However, beyond ITER, several issues must still be resolved to harness fusion power. All nations engaged in magnetic fusion research are now planning to move towards the design of a DEMOnstration Power Reactor, demonstrating the production of several hundred MW of net electricity with a closed fuel-cycle, high level of safety, and low environmental impact. Countries will face differing energy needs in the future, and therefore consider different timeline strategies for fusion development. In general, the greater the perceived urgency for fusion energy the greater is the willingness to take larger steps and larger technical risks. China, for example, expects a large increase in energy demand in the next decades. Consequently, the Chinese fusion roadmap is among the most ambitious, in terms of both goals and timescale for next steps.

EFDA has published a roadmap which outlines how to supply fusion electricity to the grid by 2050. The ***roadmap to the realization of fusion energy*** (link for download: http://www.efda.org/wpcms/wp-content/uploads/2013/01/JG12.356-web.pdf?5c1bd2) breaks the quest for fusion energy down into eight missions. For each mission, it reviews the current status of research, identifies open issues, proposes a research and development programme and estimates the required resources. In parallel a *Group for the assessment of the EU R&D Programme on DEMO structural and high-heat flux materials* (MAG) has been set up to assess and report on the Materials R&D Programme required for DEMO.

The key findings and recommendations of this roadmap are briefly discussed below.

ITER is the key facility in the roadmap and the European laboratories should focus their effort on its exploitation. To ensure its success, its operation should be prepared on JET, JT-60SA and on suitable small and medium sized tokamaks worldwide.

A solution for the heat exhaust in the fusion power plant is probably the main challenge towards the realization of magnetic confinement fusion. The risk exists that the divertor concept to be used by ITER cannot be extrapolated to a fusion power plant. Hence, a parallel, aggressive programme on alternative solutions for the divertor is necessary. Some concepts are already being tested at proof-of-principle level and their technical feasibility in a fusion power plant is being assessed. A dedicated test on specifically upgraded existing facilities or on a dedicated Divertor Tokamak Test (DTT) facility could be necessary.



A dedicated neutron source is needed for material development. Irradiation studies up to ~30 dpa with a fusion neutron spectrum are needed before the DEMO design can be finalized. While a full performance IFMIF would provide the ideal fusion neutron source, the schedule for demonstration of fusion electricity by 2050 requires the acceleration of material testing. The possibility of an early start to an IFMIF-like device with a reduced specification (e.g. an upgrade of the IFMIF EVEDA hardware) or a staged IFMIF programme should be assessed soon. A selection should be made early in Horizon 2020 of risk-mitigation materials for structural, plasma-facing and high-heat flux zones of the breeding blanket and divertor areas of DEMO, also seeking synergy with other advanced material programmes outside fusion.

The R&D to ensure tritium self-sufficiency should be strengthened. The leading role will be played by the ITER Test Blanket Module (TBM) programme. However, the DEMO blanket selection will be made taking into account the constraints on coolant and breeder arising from the choice of an efficient Balance of Plant. As risk mitigation strategy it is seen as necessary to foresee the evaluation, and potentially, the development, in addition to the two TBM designs based on the use of helium as coolant, of parallel lines such as a water-cooled lithium lead design.

DEMO design will benefit largely from the experience that is being gained with the ITER construction. An integrated design oriented approach is essential from the very beginning, to better understand the problems and evaluate the impact of uncertainties and technical risks of foreseeable technical solutions; to identify design trade-offs and constraints to address most urgent issues in physics, technology and system engineering integration; and to prioritize R&D needs. Modest targeted investments in integrated design and system development (magnets, heating and current drive, vacuum pumping system and remote handling), safety and analysis of cost minimisation strategies are expected in Horizon 2020. Substantial investments for the construction of medium and large prototypes are expected during the engineering design activity (2021-2030).

Industry must be involved early in the DEMO definition and design. Industry must be able to take full responsibility for the commercial fusion power plant after successful DEMO operation. For this reason, DEMO cannot be defined and designed by research laboratories alone, but requires the full involvement of industry in all technological and systems aspects of the design.

The EU Stellarator programme should focus on the optimised HELIAS line. The stellarator is a possible long-term alternative to a tokamak Fusion Power Plant. In addition, it provides a support to the ITER physics programme. For Horizon 2020, the main priority should be the completion and start of scientific exploitation of the stellarator Wendelstein 7-X with full exploitation under steady-state conditions achieved beyond 2020. If W7-X confirms the good properties of optimised stellarators, a next step HELIAS burning plasma experimental device will be required to address the specific dynamics of a stellarator burning plasma.

Theory and modelling effort in plasma and material physics is crucial to extrapolate the available physics results to ITER and a fusion power plant. This is crucial for the extrapolation of the core and edge plasma dynamics for both tokamaks and stellarators. Material computer modelling needs to play an increasing role in the development of fusion materials to guide and interpret fission irradiations using isotopic tailoring and to predict and interpret the fusion irradiations at low doses and hence to help guide and shape the mission of an 'early stage' to the IFMIF programme.

Europe should seek all the opportunities for international collaborations. Some of the ITER parties have a very aggressive programme in fusion and Europe can clearly benefit by the participation in the design, construction and operation of their facilities. **Already the Broader Approach with Japan is a good example of a positive collaboration that can give further advantages on the time scale considered here.**

(*Gianfranco Federici*)