

# Ex-post evaluation of the European Fusion Energy Research Programme of the 6<sup>th</sup> research framework programme (EURATOM)

Evaluation Report  
(Contract number – RTD/J.1/01/2008)

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October 2008

## **Ex-post evaluation of the European Fusion Energy Research Programme of the 6<sup>th</sup> Framework Programme (EURATOM)**

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The present ex-post evaluation of the European Fusion Energy Research Programme is carried out as part of the formal requirements comprised in the 6<sup>th</sup> Research Framework Programme Decisions and in the Financial Regulation. Furthermore, the 7<sup>th</sup> Framework Programme Decisions both stipulate that the future interim evaluation of 7<sup>th</sup> Framework Programme will build on the ex-post evaluation of the 6<sup>th</sup> Research Framework Programme.

The evaluation of 6<sup>th</sup> Research Framework Programme will be carried out in 2008 by a panel of independent high-level experts. It shall address the rationale, implementation and achievements of the programme. In support of this exercise an extensive evidence base shall be provided in the form of evaluation studies of the research activities under the 6<sup>th</sup> Research Framework Programme.

The ex-post evaluation of the European Fusion Energy Research Programme of EURATOM FP6 has been conducted under  
Contract number – RTD/J.1/01/2008

by

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October 2008

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## Evaluation Report

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## **0 Foreword**

This report contains an account of the work carried out and the findings during the ex-post evaluation of the European Fusion Energy Research Programme of FP6. The ex-post evaluation was performed in the first half of 2008 by Dr. Jørgen Kjems according to the Terms of Reference in the contract number – RTD/J.1/01/2008. The report followed the technical specification set for conducting the ex-post evaluation as defined in the relevant Terms of Reference.

The evaluation is a strategic review directed at the programme level of the EURATOM Fusion Programme during FP6. It does not represent a peer review of the specific activities in the Association and EFDA (European Fusion Development Agreement) Close Support Units selected for the case studies. The observations from these case studies have been used to corroborate specific points in the assessment of the Fusion Programme as a whole.

The evaluation has been met with professionalism, courtesy and frankness during the interactions with DG Research (RTD) and during all the interviews and site visits. Supplementary information has been readily provided in a spirit of openness and collaboration. This has made the task of conducting the evaluation both pleasant and rewarding. I should like to thank all the parties involved for their help and support.

Frederiksberg, October, 2008

Jørgen Kjems

## **1 Executive summary**

Conclusion: The European Fusion Programme has fulfilled its objectives during the 6<sup>th</sup> Framework Programme (FP6). The programme has made decisive progress towards the realisation of the Next Step, ITER, within the framework of international cooperation. The programme has executed the planned, coordinated activities regarding exploitation of JET and technological research, in particular research into materials for fusion. The knowledge base for ITER construction and operation and for DEMO design has been significantly expanded.

The main findings of the ex-post evaluation of the European Fusion Energy Research Programme implemented from 2002 to 2006 and issues to be considered for the future development of the programme are the following:

***i) The European Fusion Programme (henceforth "the programme") has strengthened its leading global role during FP6.***

Evidence of this is the international agreement on ITER reached in 2006 and the decision to locate ITER in Europe with a significant share of the construction going to EURATOM. Furthermore, significant enhancements of the capabilities of JET and the other European facilities were achieved, and the programme has also become more coherent and has augmented its strength in fusion technology through the EFDA activities.

Issues to be considered:

- The programme has become more complex to manage combining efforts on global, European and national scale. The realisation of ITER is already a challenge which will require sustained, large and focused efforts, especially by EURATOM.
- Time is of the essence due to the growing need for an abundant new energy sources, increasing political awareness and desires for fast-track scenarios.
- The fast-track cannot be delivered within the current budget envelopes, according to the opinions expressed during this evaluation albeit that the realisation of ITER is an integral part of a fast-track strategy, and that the construction and exploitation plus the follow-up elements already go beyond the financial envelope and time horizons of FP6.

***ii) The programme has overcome the uncertainties caused by the hiatus in the international negotiations until 2005 and adapted quickly to the new situation.***

Evidence of this is the decisions to prolong, enhance and jointly exploit the JET-facility under the EFDA agreement. Similarly, the prioritisation of the joint technology activities under EFDA has provided the necessary base for ITER construction, and there has been a significant re-orientation of programmes in the Associations towards ITER needs.

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### Issues to be considered:

- The diversity and balance of efforts directed towards ITER, fusion energy technology and the underlying physics, as well as efforts on alternative configurations.
- The focusing of the programme's efforts which should be helped by the recently completed fusion facilities review.
- The optimum complement of staff, i.e. engineers versus physicists, to match the evolving needs.

### ***iii) The programme has followed the related work programmes and also responded properly and promptly to strategic advice received from its advisory bodies and the programme monitoring activities during FP6.***

Evidence is the finding that recommendations of the 2002 monitoring report have been adequately taken into account in the definition of the programme activities and objectives, and the annual work programme goals reflect the overall programme goals. It also found that these goals have permeated to the operational level in the Associations.

### Issues to be considered:

- The interviews show that some of the actors find the EFDA system and committee structure "cumbersome", but probably necessary, and continued attention to streamlining is required.
- The planning system, execution and monitoring activities involve many interfaces with inherent risks for stakeholders' frustration and bottle-necks.
- Some interviews pointed to the risk that the complex structure of the fusion programme might in the future impede a global optimisation of the international sharing of work.

### ***iv) The programme has been implemented in a transparent, precise and coherent manner through Association programmes and joint programmes, tasks and projects between the Associations, the EFDA Close Support Units (CSU) and the European Commission.***

Evidence for this is the new mode of managing the enhancements and the exploitation of JET. In addition to the industrial procurement, there have been calls for participation for Associations, which were subsequently shaped and prioritised in an open process that included all stakeholders. Similarly, the joint planning and execution of EFDA technology tasks have been carried out with frequent dialogues between the EFDA CSU teams and the Associations. The planning and monitoring activities of the EFDA Science and Technology Advisory Committee (STAC) have also been conducted in a transparent manner, which rests on the tradition of a frank and constructive dialogue in the advisory committee system.

### Issues to be considered:

- The balance of the responsibility of Associations, EC and the EFDA system; and the ITER system and the international partners. On one hand, some of the exploratory work could be adequately managed by the Associations alone

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- following agreed strategies and targets, while on the other hand, some of the more targeted joint work could benefit from a strengthening of the project culture and management.
- There has been an increase in the involvement of competences outside the Fusion Programme during FP6, but more could be done according to many of the interviews.
  - A limited amount of competition between Associations, in order to promote excellence, should be considered.

### **v) The programme has effectively and efficiently achieved significant new results of high quality over a wide range of topics.**

Evidence for this is best documented via the review of the programme conducted by the EURATOM Scientific and Technical Committee (STC) who pointed to:

- Successful exploitation of JET, in particular relevant results for ITER
- Advances in high-power heating and current drive technology for ITER
- Sophisticated plasma stability control tools
- "High-Z" metal tungsten first wall technology for tokamaks like ITER
- Increased integration with the involvement of contributions from smaller associations
- Launching of the EVEDA (Engineering Validation Engineering Design Activities) phase of the IFMIF fusion materials test facility
- European study of possible Tokamak fusion power plants
- Demonstration of ITER-relevant advanced plasma confinement modes

### Issues to be considered:

- There has been a significant delay in the construction of Wendelstein-7X Stellarator, which remains a challenge.
- The balance between short- and medium- term technology goals connected to the needs of ITER, and longer-term exploration of fusion physics and alternative configurations for the programme as a whole.

### **vi) The programme has become more attractive during FP6.**

Evidence for this is the number of associations which grew to 23 during FP6, and the programme is well underway to have associations in all the new Member States. The case studies show that the number of students in fusion-relevant areas has increased at the respective associations and the affiliated universities. Outreach activities like "fusion expo" and the multi-lingual web sites have been met with good responses. After the ITER decision the programme is also met with growing interest and expectations from the public, students and new staff.

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### Issues to be considered:

- The recruitment of new staff has sometimes been characterised as "difficult but not impossible" – meaning that it has taken both time and effort to fill the vacancies.
- The programme will have to continue the work to reduce the image of a "closed community" to outside stakeholders.

**vii) The programme has addressed the human resource issues in an effective manner and has contributed to researcher mobility in Europe, training of young researchers and broadening of the science base.**

Evidence for this is the continued and expanded mobility scheme to include new Member States during FP6. This has allowed for increased movement of researchers between associations. A new training scheme aimed at engineers in fusion-specific disciplines has been launched successfully together with a EURATOM Fellowship Scheme for individual post-doctoral researchers. A continued high number of PhD-students have joined the associations.

### Issues to be considered:

- The age profile of the population of fusion scientists needs to be considered if future recruitment is mainly directed towards engineers.
- The gender balance.

**viii) The European Fusion Programme has demonstrated clear, added Community value during FP6 with continued contributions to the long-term sustainable energy policy, advancement and spin-off of technology and pioneering of the development of the European Research Area**

Evidence for this is the consensus opinion met by the evaluation that the scientific and technological feasibility of fusion energy has become more credible during FP6; that fast-track scenarios are realisable if given sufficient political and economic support; that the transfer of advanced technology to industry has been conducted as an integral part of the programme strategy; and that there are many examples of technological spin-off to other sectors like health, power, materials and materials processing.

The Fusion Programme and the EFDA concept for transnational cooperation are unique in Europe and should be a European Research Area model for other areas of science i.e. the implementation of the SET-Plan.

### Issues to be considered:

- The development of new forms of global collaboration around ITER has become a new challenge for the European Programme
- The development of the long-term relations with industry, which increasingly appears to be guided more and more by shorter-term interests and goals than the long-term perspectives of fusion as a new source of energy.

## **2 The Fusion Programme during FP6**

The long-term objective of the European Fusion Programme is the harnessing of the power of fusion to help meet the future needs for abundant and sustainable energy. This is a long-term effort stretching over decades and the work during FP6 (2002-2006) should be seen in this perspective.

The Council Decision of September 30, 2002 (2002/837/Euratom) concerning the six framework programme adopting a specific programme (Euratom) for research and training on nuclear energy (2002-2006) states:

### ***Objectives:***

*Fusion energy could contribute in the second half of the century to the emission-free large-scale production of base-load electricity. The advances made in fusion energy research justify further pursuing a vigorous effort towards the long-term objective of a fusion power plant. Theoretical work and experimental studies on the existing devices world-wide, in particular on JET, have established the scientific and technical readiness for the construction of a project of the next generation after JET with the objective of demonstrating the scientific and technological feasibility of fusion energy. World wide collaboration on fusion energy research has progressed to the detailed engineering design of such a Next Step device, ITER, with the objectives of extended burn in inductive operation with power amplification  $Q > 10$ , demonstrating generation of 400 MW of fusion power over about 400 seconds, that could allow burning plasmas to be studied in conditions relevant to energy production.*

*The successful completion of the ITER Engineering Design Activities makes it possible, in line with the reactor orientation of the Community activities on fusion energy research, to take a decision about the realisation of the Next Step. Subject to a positive outcome of the international negotiations on the legal and institutional conditions of the establishment of an ITER Legal Entity and negotiations for its joint implementation (construction, operation, exploitation and decommissioning), a specific decision could be sought in the period 2003-2004, so that construction could effectively start during the period 2005-2006. The period 2003-2006 has therefore to be seen as a transition period marked by the need to rationalise European activities due to the strong orientation of the programme towards the Next Step. If and when decided, the realisation of the Next Step will mobilise significant human and financial resources.*

*Once a decision is taken to go ahead with the project, adaptations to the current efforts of the European partners of Euratom in the field of fusion and organisational changes will be required, in particular to steer*

*jointly the European contribution to ITER. The continuation of a meaningful R&D programme will be ensured, including the transition between the activities currently carried out in the framework of the Associations (1) and JET, and what would become the 'accompanying programme' in physics and technology for fusion once the construction of the Next Step/ITER device, if decided, has reached its steady state after 2006.*

### ***Priorities***

*(i) Associations' programme in physics and technology*

*The Associations' programme will include:*

*— R&D in fusion physics and plasma engineering, focusing on the preparation of ITER operation and the study and evaluation of toroidal magnetic confinement formulas, with in particular the continuation of the construction of the Wendelstein 7-X 'stellarator' and operation of the existing installations in the Euratom Associations.*

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— *Structured R&D activities in fusion technology in particular research on fusion materials and participation in the R&D activities for the decommissioning of JET, which is foreseen at the end of its operations.*

— *Investigations of socio-economic aspects, focusing on evaluation of economic costs and social acceptability of fusion energy, by way of complement to the further studies on safety and environmental aspects; coordination, in the context of a keep-in-touch activity, of the Member States' civil research activities on inertial confinement and possible alternative concepts; dissemination of results and the diffusion of information to the public; mobility and training. In contributing to the Associations' programme, priority will be given to multilateral actions to focalise activities on common projects such as those directly related to operation on JET and to the Next Step/ITER and/or staff training. Depending on a decision on the realisation of ITER and its timing, the current Community support to the Associations' activities will be adjusted, and the phasing out of the exploitation of a number of facilities will be considered. Adequate means shall be ensured to maintain a strong European coordination of the fusion activities, which has demonstrated its usefulness over the years. The extent of the accompanying domestic programme in fusion physics and technology which is required in the Associations and European industry to take full benefit from ITER, will depend (a) on the level of the European share in ITER and (b) on where it would be sited. This could entail investments aiming at maintaining experimentation on fusion devices at world-class level in Europe beyond the start of operation of ITER and an adequate programme of technological development.*

### *(ii) Exploitation of the JET facilities*

*The JET facilities will continue to be exploited in the framework of the European Fusion Development Agreement (EFDA), in view of preparing the ITER operation by completing the exploitation of the performance enhancements currently under way. The use of the JET facilities should be phased out progressively according to the schedule of the ITER realisation and to the availability of the necessary financial resources.*

### *(iii) Next Step/ITER*

*The Proposal for the Euratom framework programme (2002-2006) includes the continuation of Next Step activities with a view to participating in its construction in the second half of the period. However, since decisions on ITER do not depend only upon European Union Institutions but also on the European Union international partners, the proposed programme of activities must be open regarding the eventual siting and framework of the Next Step/ITER and the precise content of the accompanying domestic programme. The studies performed in preparation of possible European site(s) will be completed. The European Union participation in ITER would include contributions to the construction of equipment and installations, which are within the perimeter of the ITER site and necessary for its exploitation, as well as to the costs associated with the staffing and management of, and the support to be given to, the project during construction. The level and nature of this participation will depend on the outcome of the negotiations with the European Union international partners, and in turn on the location of the ITER site. If ITER was located in Europe, the European Union participation would also include contribution to the costs to be borne by Europe as a Host Party.*

In June 2005 the international partners agreed on the ITER site in Europe and to proceed towards an international agreement on the construction and utilisation of ITER. This was the major, singular event in the European Fusion Programme during FP6 consolidating EU's leading role in the field. The preparation for the Next Step had been pivotal during FP4, and it was a central goal in FP5. It became the dominant theme in FP6. The ITER agreement, signed on 22 November 2006, signals the start of a joint global effort in fusion energy research, which in turn has substantial impact on strategy, planning and execution of the European programme. During FP6 the European programme made significant strides to adapt to this new situation. Some of these changes had already been

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prepared during FP5, with the creation of EFDA and the transformation in the organisation and utilisation of JET. It was during FP6 that the practical consequences came to light and the new distribution of roles and tasks within the programme were developed and first experiences gained.

The response of the Fusion Energy Research Programme has been a significant increase in the degree of integration in (1) the EFDA programmes concerning the enhancement and exploitation of JET and the development of fusion technology, and (2) the work of the associations with new clusters formed, and increased use of the individual facilities by other associations. The process of integration has been carried out in the spirit of the European Research Area, ERA. The Fusion Programme is often referred to as the front-runner in the development of models and practices for research cooperation in Europe. During FP6 the Fusion Energy Research Programme has demonstrated a significant ability to adapt to changes in the external constraints (uncertainty of future developments) and, collectively, to set and pursue new goals with an even higher degree of integration than before. The procedures and practices developed during FP6 are good practical examples of European cooperation and illustrate the strength of the ERA concept.

The final decision to locate ITER in Europe bears evidence to the leading role of the European Fusion Programme on the global scene. It resulted from a strong collective effort by the programme managed by the Commission, and is seen universally by the respondents in this evaluation as the major achievement during FP6.

### **Profile of the EURATOM Fusion Energy Research Programme:**

- Joint European effort under the EURATOM Framework Programme
- Part of overall FP6 research effort in Cleaner Energy Systems
- Aligned with global EU policies on energy and sustainability
- Involves 2000 professionals in 27+1 European countries
- Organised with 23 (2002), now 26 (2008) Fusion Research Associations
- About 250 PhD-students are currently trained at the Associations
- Operates JET, together with 8 other large and 4 medium-sized facilities
- Jointly managed by the European Commission and the member states through EFDA and the Framework Programme Committees
- Total annual budget of about 500 MEuros of which -on average- 206 million Euros is community support

### **3 Objectives and scope of the evaluation**

The evaluation has addressed the issues of rationale, implementation and achievements of the programme at the strategic level. It has been aimed at evaluating the quality of the fusion energy research activities, the quality of their implementation and management and the progress made by these research activities towards the relevant objectives, as

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defined in FP6 (EURATOM). The evaluation also aimed to give an assessment of the Community added value of the fusion energy research activities and their results.

### **3.1 Methodology**

The evaluation has been performed by a senior independent consultant, Jørgen K. KJEMS, and it has followed the scope and issues defined in the ToR (Annex B). It has used the approach and methodology outlined briefly in the following. The ex-post evaluation is based on the extensive documentation provided by the Commission Services, DG RTD/J.1, combined with case studies of the work in specific areas of the Fusion Programme as indicated in the Terms of Reference and specified through consultations with the DG RTD. The list of documents provided is shown as Annex C. The case studies are listed and described in Annex A. The desk studies of the documentation have been combined with five site visits and more than 20 in-depth interviews lasting 1-2 hours with key actors in the associations selected for the case studies, EFDA managers and personnel and members of the fusions programme committees. Shorter interviews have also been carried out with stakeholders in ministries and agencies as well as a member of the US ITER team in order to collect outside views on the programme. A list of the interviewed persons is attached as Annex D.

## **4 Strategy and goals of the Fusion Energy Research Programme**

### **4.1 Strategic management**

The evaluation has addressed this issue from a global perspective and from a European strategic perspective.

Global perspective: The ITER agreement was reached during FP6 (signed in November 2006) and the outcome documents the global competitiveness of the European fusion community and the fusion energy research programme. The evaluation explored, through interviews, what were the most important success factors perceived by the key actors and stakeholders.

Observations: The European Fusion Programme is seen by all parties interviewed as world leading. It has the strongest Tokamak oriented R&D effort with the JET as the global premier ITER-relevant facility. It is a truly European integrated programme which takes advantage of strong national efforts centred at very competitive, specialised facilities that explore fusion reactor relevant operating and control conditions.

The programme has followed a clear strategy towards the overriding goal in the programme decision namely, the realisation of an energy-producing fusion reactor. This goal has been pursued with a balanced effort on (1) ITER as the next step; (2) reactor-relevant technology development; and (3) scientific research for longer-term improvements.

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The programme has proven to be very robust in the period at the beginning of FP6 where the political decision on ITER was pending. During this period the programme and its leaders in the Commission and in the member states demonstrated commitment and resolve in support of the ITER project. This was viewed by many stakeholders as the key to the success.

The track record and performance of the European Fusion Energy Programme at the start of FP6 formed the credible base on which the European political system could broker a deal with the international partners in ITER and in particular with Japan. This led to the most significant achievement of the Fusion Programme during FP6 and arguably for the whole FP6: - the international agreement in 2006 to construct ITER and the selection of the European site at Cadarache.

Strategy: Over a longer period of time, the Fusion Programme has been guided by a 3-pronged strategy: Next Step, Technology and Improved concepts including Stellarators. The evaluation has explored the appropriateness of the chosen balance between the three strands in the light of the “fast-track” option and the global developments. The evidence can be found in the recorded discussions of the programme in the high-level committees and through the interviews.

Observations: The Fusion Programme is unique in Europe. It is part of the EURATOM Framework Programme which provides about 40% of the total funding, and most of the R&D efforts are carried out through bilateral association agreements with organisations in the member states, which again provided about 60% of the funding in the FP6 period 2002-2006.

In 1999, the Fusion Programme partners formed the European Fusion Development Agreement (EFDA) in order to enhance the integration and ability to take on common R&D tasks for the exploitation of JET, the development of ITER and reactor-relevant technologies. The overall strategic management of the Fusion Programme is handled by the Commission in consultation with the CCE-FU and its sub-committees. The EFDA steering committee develops strategies and guidelines for the EFDA activities within the envelope of the Fusion Programme. The work of the individual associations is planned and supervised by steering committees where member state organisations and the Commission are represented. Important management tools are the annual work programmes and the monitoring thereof.

It is inherently a complex system with many actors and stakeholders, but the interviews express the general opinion that the system has been working well during FP6. A reform of the committee structure has been carried through at the end of the FP6 period. This has led to fewer and smaller sub-committees and more frequent use of ad-hoc committees, a fact that has been seen as a positive development by all the participants in the review.

The main strategic challenge for all aspects of the strategic programme management during FP6 has been the accommodation of the ITER project and the relations to the

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international partners. The European programme has to increasingly act as a united entity towards the ITER organisation and the international partners.

EFDA has developed significantly during FP6, and the legal entity to serve as the interfaces to ITER, F4E, was conceived and prepared during FP6. EFDA and F4E are both seen as adequate organisational responses to the managerial challenges. It is widely acknowledged among the respondents to this evaluation that the Fusion Programme has achieved a new degree of integration in the ERA spirit during FP6. The exploitation of JET has become a truly common endeavour, the number of other collaborative projects between associations has increased including a broad range of EFDA technology tasks, several of the large national facilities have developed into more common user facilities, and the mobility and training activities have increased.

The concept of a fast track to fusion was introduced in 2001 with DEMO as the new next step after realisation of ITER. Fast-track scenarios have become more attractive for facing the global energy and climate challenges. The presentations of the new European Strategic Energy Plan, – the SET-Plan, illustrates the potential contribution, from fusion power to global energy needs, as a rising sun in the 2050 time frame. It would take a large-scale, fast-track effort to achieve a significant contribution to world energy needs in that time frame. The European Fusion Programme has operated with an almost constant spending rate of about 500 MEuros/year (2006 prices) during FP4, FP5 and FP6. This has meant that unforeseen events and cost escalations in general have been accommodated by delays with the Wendelstein 7-X stellarator delay of 8 years as the most extreme example. Less visible are the delays in the long-term technology efforts which have also occurred when short-term R&D issues associated with ITER have needed additional resources. It should be noted that the amount of preferential support from the Commission to a given project has not been escalated in case of delays.

During the interviews, I have found the general opinion that a fast-track strategy can only be realistically pursued with more resources allocated to the program. A fast-track scenario is still a long-term endeavour, which needs both concentrated medium-term efforts on ITER, IFMIF and DEMO design, and longer-term efforts to maintain a broad European wide base of R&D for the purpose of promoting talent, ideas and technologies that can ultimately make fusion energy competitive. It should be noted that the fast-track scenario does not stop at the DEMO design but goes beyond to create the know-how base to build “prototype fusion reactors”. It is a new development that the Fusion Energy Programme scenarios are becoming time constrained. The industrialised world needs a new large-scale source of sustainable energy supply by the middle of this century. This is a consequence of the European energy policy and the urgency of the global need for a new, large-scale, sustainable energy source. Fast-track scenarios represent the appropriate response to this urgency, but they will require substantial increases in the spending rates. They may also be prudent economically in order to optimise the balance between annual spending and integrated cost to achieve the goal.

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I have also come across the opinion among many of the leaders that it is crucial that ITER be given the highest priority to prove, without delay, the feasibility of a Tokamak fusion energy-producing reactor and that the European Fusion Energy Research Programme has a special responsibility as the lead partner to secure the success of the ITER endeavour. This will require a continued, very competent and focused effort at all levels of management of the European Programme and in the interactions with ITER.

### **4.2 Programme goals**

The evaluation has explored how the specific programme goals were chosen in light of the overall FP6 goals for the Fusion Programme as a whole and the chosen strategy. This has been done by desk study of the relations between the FP6 objectives and the evolving objectives in the annual programmes as well as by the interviews.

Observations: The annual work programmes have closely followed the scientific and technological objectives, broad lines of activities and priorities for the FP6 Fusion Energy Research Programme. The annual EURATOM Work Programmes have specified the objectives and scope for the different activities and have broadly defined priorities and goals for a given year. The priorities and goals have appropriately taken into account the progress achieved, monitoring results and external developments like the progress and needs for the ITER process. The results of the 2002-specific monitoring report of FP5 have been adequately taken into account. An appropriate balance has existed between orientation towards new priorities and task and continuity.

There is clear evidence in the planning material for the associations that the priorities and goals from the annual work programme penetrate to the operational level. The same holds for the EFDA activities associated with technology and preparation for ITER. This reflects the long-standing tradition of an intense bottom-up and top-down dialogue that has evolved in the Fusion Programme over the years. Many researchers feel that they have been part of the planning loop at different stages, and this has resulted in a broad consensus around the work plans. This dialogue has increased in intensity, both vertically and horizontally, during FP6. The case studies show that managers at many levels have taken initiatives to stimulate this development, which has resulted in an increased amount of cooperation between the associations and joint responses to the calls for participation in the EFDA tasks, both for the exploitation of JET and for the technology programme. The interviews also showed that the partners from the new member states felt included in the dialogue. Often with help and support from the Commission representatives. The working mode of the Fusion Programme during FP6 is a model example of European cooperation at programme level following the ERA concept to unite complementary competences, to focus on the agreed priorities and to avoid duplication of effort.

### **4.3 Funding**

The Fusion Programme has experienced a relatively constant financial envelope with balanced contributions from the member states in the associations and the EURATOM

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programmes. During FP6 the distribution of budgets had to change because of the increasing funding needs for the activities related to the Next Step. At the same time the programme had to prepare for budget trajectories with substantial increases of the ITER budget and in the European support activities for ITER. The evaluation has explored how these challenges were met and tries to identify the successes and shortcomings in the budget allocation process through interviews with the key actors.

Observations: It is the general impression that the overall funding situation for the Fusion Programme has been adequate during FP6. This is mainly due to the delay in the decision on ITER, which has required fewer resources than foreseen for the short-term Next Step activities, thus leaving room in the budgets for the ITER-relevant activities in EFDA and JET. It has also made it economically feasible to extend the operations of JET until 2010 and to complete the enhancement programme 1 (EP1) and initiate the enhancement programme 2 (EP2) at JET.

The associations have felt that they have been more constrained financially, even though the overall activity level has roughly been maintained. In particular, the smaller associations have felt a squeeze between the need to orient themselves towards the common projects where they often have a contributing role, and the need to compete for national funds, which are distributed with different priorities and criteria. The special allocation of funds for cooperation has helped alleviate this pressure, especially for the smaller associations.

Wendelstein-7X at the IPP in Greifswald is a special case with substantial cost overruns and delays. During FP6 it has been possible for the IPP management and the European and national programme to bring the project on a robust course towards completion, following a critical review and substantial changes in the project, management, modes of execution and budgets.

## **5 Programme implementation**

### **5.1 Efficiency**

The evaluation has gauged the efficiency through comparisons of the productivity indicators for similar institutions as the ones selected for the case studies – both nationally and internationally. This has been done by use of available benchmarking indicators and reports and through an analysis of annual reports combined with information from interviews with management representatives. Efficiency of the programme management activities at the EC has been assessed through benchmarking with other FP6 programme activities.

Observations: The overall efficiency of the implementation of the programme has been good. The programme has on the whole achieved the goals that were set out for FP6 with the ITER decisions as a major management success for the Commission together with the other leaders in the program.

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The analysis of the different cases of activities also shows a high degree of efficiency – again with Wendelstein 7X as the exception. As mentioned above, this project is now progressing in an efficient manner.

The output in terms of publications from the associations has been at a reasonable level compared to other fields with a similar combination of scientific research and technological development, like good technical universities. The Fusion Programme tends to have a higher proportion of publications in conference proceedings compared to regular scientific journals. The leaders of the associations in the case studies were aware of this, and actions have been taken to rationalise the situation. The regular fusion energy conferences form an essential global forum for presentation and discussions of the progress in the different sub-fields. It is important for the European programme to be well represented at these conferences. This is generally the case during FP6. Publication in reputed scientific journals enables communication of new scientific results to the scientific community at large outside fusion. This is important for the exchange of knowledge and ideas and it is generally recognised as an indicator of scientific activity, output and quality. Hence it is also important for the career prospects of young scientists. Issues for the future development of the programme are the balance of the responsibility of associations, EC and EFDA system, and the ITER system and the international partners. On one hand some the exploratory work could be adequately managed by the associations following agreed strategies, while some of the more targeted joint work could benefit from a strengthening of the project management and culture. There has been an increase in the involvement of competences outside the Fusion Programme during FP6, but more could be done according to many of the interviews.

### **5.2 Effectiveness**

The effectiveness has been evaluated with indicators of the rate of progress and the pursuit of near-term and long-term objectives using the technology programme as case. It will be evaluated on the basis of the written progress report and interviews with key actors in the technology programme.

Observations: Effectiveness is achieved by doing the right things at the right time. The Fusion Programme is characterised by a strong strategic management. This has ensured that the programme as a whole has been conducted in an effective manner. The strategic management permeates to the individual programmes and technology tasks in the associations. In EFDA, this is assured by the monitoring by the STAC, and for the work of the associations, it is the responsibility of the steering committees. The documentation shows that this system of planning and monitoring has worked well during FP6. The monitoring of STAC has been very comprehensive with specific coverage of each of the 25 different tasks. The monitoring by the steering committees has generally covered broader areas, but has done so without sacrificing effectiveness.

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In the relations with industry the actors in the Fusion Programme have experienced situations with reduced effectiveness. There are many examples of both efficient and effective relations with industry. They typically relate to situations with purchases of well defined components or systems in a market with several qualified suppliers. The more challenging situations have occurred, when the industrial orders contained an element of development and adaptation of either the design or the manufacturing procedures. This situation has caused delays and failure to meet specifications. This trend is aggravated during FP6 where the programme has experienced a reduction of the number of industries that are able and willing to enter into such contracts. The reasons given have been change of business strategy, often as a result of mergers and/or reorganisations. Some industries also find that the contracts represent business opportunities that are too limited in the short and medium term. There are also good examples of long standing relations in the form of partnerships with individual companies which have managed to solve or circumvent such problems. The development of the Eurofer - the qualified steel for ITER -, gyrotrons, and high heat flux components are the results of successful partnerships of this kind. Some of the industrial deliveries for Wendelstein 7X are examples of the opposite trend. The effective relations to industry that has been developed by CERN were pointed to in several of the interviews as interesting and successful models.

### **5.3 Transparency**

The evaluation has explored the transparency in the implementation process via the interviews on how the different actors and stakeholders experienced the FP process in both planning and implementation.

Observations: The Fusion Programme as a whole in FP6 has been conducted in a very transparent manner within the programme. This has been found to be true at the different levels of decision making. It is partly a consequence of the overall organisation of the programme, which is based on an intense dialogue between the different levels and actors. The annual work programmes clearly reflect the FP6 programme goals, and the annual work programmes penetrate via an intense dialogue to the annual programmes for the associations and the EFDA activities. This ensures an adequate level of transparency within the programme. The transparency and openness have been especially appreciated by the members of the recent associations in the new member states. All the relevant information is also accessible to the general public via the internet and via reports and other publications.

The Fusion Programme is often seen from the outside by external stakeholders as a “closed shop” with a lesser degree of transparency. During FP6 several steps have been taken to open up for a dialogue with other scientific disciplines. Examples are the formation of the ERA-Net EXTREMAT, where groups from different fields working with materials under extreme condition collaborate. Another example is the participation by EFDA JET in the association of European, intergovernmental research institutions, EIROFORUM. Other experiences that have increased the number of links to the outside academic world have been broadening the scope of the yearly plasma physics and fusion

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technology conferences to include general themes like turbulent flow in combination with Tokamak physics.

### **5.4 Handling of contracts**

The evaluation of the handling of contracts was covered via the interviews with publications. Focus has been on the interactions between the European Commission and the associations as well as the interactions between the EFDA units and the associations.

Observations: The administrative aspects of the Fusion Programme have generally been handled with high precision and timeliness during FP6. There are two opposing factors that influence the administration of the programme. On one hand, the administrative procedures for dealing with the contracts of association and handling of the financial contribution are well established and have been developed and conducted in a streamlined manner. On the other hand, the trend is an increasing number of projects that have to be developed, assessed and approved in the EFDA system. The number of interfaces in a given project has also increased. There seems to be scope for an improved division of labour with a higher - but still accountable - degree of autonomy for the participants in the longer term R&D activities, once a clear common strategy with common goals is agreed upon. On the other hand there is also scope for an even closer coordination of the technology development projects aimed at ITER and DEMO using advanced project management procedures. The case studies of the EFDA technology activities show that the research tasks are more difficult to manage centrally than the more specified development tasks. In any case, the research tasks and the technology tasks require different managerial approaches both at the central EFDA level and in the associations.

### **5.5 Attractiveness of the programme**

The evaluation has explored the "attractiveness" on the basis of the interviews with key actors at the selected associations as well as the work of the Fusion Programme's Ad-Hoc Group on HR-issues.

Observations: The developments during FP6 and especially the ITER decision have in general made the Fusion Programme more attractive. Evidence to that effect is the development in number and gender composition of students at the plasma physics and technology courses that staff from the associations gives at local universities. The case studies show that the number of student in some cases have doubled, and the gender distribution have become more even. But still, the availability of staff with the right competences and recruitment of staff has been presented as a difficult, but not impossible challenge in most of the interviews. The emphasis on ITER and DEMO technologies means that there are more tasks which require specialised engineering skills. These requirements typically exceed the available skills of the staff at the associations, and competences have to be made available through new recruitments. In many of the

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interviews it was pointed out that the Fusion Programme is often unable to meet the salary demands for this type of skilled personnel who typically come from industry. Time-limited appointments can sometimes be an additional hurdle. The Fusion Programme management has been aware of these issues. They have been analysed by an ad-hoc committee, and appropriate actions like the development of the European Fusion Training Scheme (EFTS) and the mobility programme have been successful countermeasures.

### **5.6 Ethics**

The evaluation has probed ethical issues through the interviews with key actors at the selected associations and key stakeholders.

Observations: All the evidence collected in the evaluation indicates that the Fusion Programme is carried with high ethical standards in all of its aspects. This includes the work of the commission officials, the FP6 EURATOM and EFDA committees, the work of the associations and the relations to industry.

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## 6 Achievements of the research activities.

During FP6, the EU Fusion Programme, which operates as a fully integrated R&D programme within the European Research Area, has concentrated on advancing the physics and technical basis for the construction and exploitation of ITER, on developing several device concepts which may, over the longer term, offer the potential for improved fusion power plants, and for developing the technological basis for the construction of a DEMO fusion power plant, which would be constructed subsequently to ITER and which would demonstrate the capability of fusion for electricity production. Major achievements during FP6 include:

(i) **Continued successful exploitation of the JET device** under the European Fusion Development Agreement, in which it is exploited by teams of scientists and engineers from all members and associated states of EURATOM. Scientific progress has continued in the advancement of physics understanding for ITER, and the programme has included further experiments with deuterium-tritium fuel mixtures and simulation of populations of high energy alpha particles to test understanding of physics processes which might occur in ITER.

(ii) **Substantial advances in the development of high power heating and current drive technology for ITER**, including the testing in FTU of an ITER-like antenna for current drive using lower hybrid waves, the construction of ITER-like ion cyclotron heating antennas in JET and Tore Supra, major progress in long-pulse gyrotron source technology for electron cyclotron heating through a close collaboration between the Fusion Programme and EU industry, and the development of high-energy negative ion sources for the ITER neutral injection system.

(iii) Progress has been made in the use of **sophisticated control tools** to change the plasma behaviour and to improve plasma performance: stabilisation of plasma instabilities using current drive by means of high frequency microwaves has allowed higher values of plasma pressure to be achieved following suppression of the plasma instabilities in ASDEX Upgrade FTU and TCV; the TEXTOR Dynamic Ergodic Divertor, a sophisticated magnetic control system, has been shown to generate many of the expected effects in the edge plasma and to allow access to the high confinement mode of operation; in the RFX-mod and EXTRAP-T2R reversed field pinches, an extensive array of magnetic coils has been used to control plasma instabilities which limit plasma performance in these devices, a result which may contribute to the control of such instabilities in tokamaks.

(iv) The gradual introduction of the **“high-Z” metal tungsten** as a first wall material in ASDEX Upgrade has allowed the influence of such materials, which will be used in ITER and are likely to be required in a power plant, to be studied and controlled systematically. A further enhancement of the JET device has been launched to install an all-metal first wall, combining beryllium and tungsten surfaces. Results from these two experiments will inform the final selection of first wall materials in ITER.

(v) Progress towards steady state tokamak discharges was highlighted by the successful experimentation with the CIEL high power actively cooled toroidal limiter in the superconducting tokamak Tore Supra. It has allowed **the achievement of 400 s plasma pulses during which 1 thousand million Joules of energy** were injected into and extracted from a plasma in which the current was entirely driven by non-inductive techniques, as will be the case in a continuous tokamak reactor.

(vi) The integration of developments across the fusion associations, **successfully drawing also on the contributions by the smaller associations** in measurement systems, real time control, heating and current drive techniques and theoretical studies. The operation of smaller devices which provide invaluable training opportunities for young researchers.

(vii) A proposal for an accelerated “EVEDA” (Engineering Validation and Engineering Design Activity) phase of the **proposed IFMIF fusion materials test facility** has been developed to allow a more rapid advance towards construction of the device. A **European study of possible tokamak fusion power plants** (Power Plant Conceptual Study) has been completed confirming the environmental and safety advantages of fusion power plants and concluding that with reasonable progress in science and technology such plants will be economically viable.

(viii) The demonstration of **advanced plasma confinement modes** on several European experimental devices should lead to ITER operation beyond its reference scenario. This is of high importance for the preparation of DEMO.

### **6.1 Major achievements of the EURATOM Fusion Energy Research programme**

The EURATOM Scientific and Technical Committee has evaluated the progress of the Fusion Programme during the FP6 period (2002-2006) in the beginning of 2007. Their findings are reproduced in the table above. The findings in the present evaluation concerning major achievements of the Fusion Energy Research Programme during FP6 are entirely consistent with the findings of the EURATOM STC of which the evaluator is a member.

### **6.2 Advances towards programme goals**

The evaluation aims at the programme level and has attempted to gauge the effectiveness in relation to the programme goals that were set out for the Fusion Programme in FP6 Council decisions and in the annual work programmes. The indicators have been assessments of the annual rate of progress, as gauged from written progress and monitoring reports (quantified whenever possible and appropriate) supplemented with the personal assessments obtained in the interviews with key actors and stakeholders. The latter will be confined to the case studies that have been selected (Annex A).

Observations: The Fusion Programme has made significant advances during FP6 (2002 - 06) towards the objective to demonstrate the scientific and technological feasibility of fusion energy production. The programme has made good use of the facilities and human resources despite the hiatus in long-term decision making and the uncertainties that ensued due to the international negotiations concerning ITER. Once the decision was taken to place ITER in Europe, the programme has moved quickly to adapt to the new situation. The overall trend in the programme development during FP6 has been a steady increase in the degree of integration in preparation of the participation in ITER, and an accompanying programme directed towards both physics technology issues which lay the foundation for the design of a demonstration reactor. Europe has kept the world leading position in tokamak-oriented fusion energy research and has maintained a strong strategic position in critical areas of fusion technology. This is documented by the readiness of the critical technologies needed to construct ITER.

The programmes of the Associations have been oriented towards common projects such as those related to the exploitation or operation on JET and corresponding data interpretation, and to the Next Step / ITER. The mobility and training of scientific and technical personnel, the dissemination of results and the diffusion of information to the public have been an integral part of the activities carried out.

Enhancement and exploitation of the JET machine: This has included the completion of the enhancement programme decided in 2000 during FP6 and the launch of a second enhancement programme in particular with regard to heating, fuelling and diagnostics of relevance to ITER. The associations have contributed significantly to the exploitation of JET under a new organisational arrangement as part of EFDA agreement. This new scheme required an initial learning period and has progressively improved so that the

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experimental campaigns in 2003/4 and 2006/7 were the most intense and productive in JET's history until then. In total 13 campaigns were carried out during FP6 along with substantial enhancement activities. The experience expressed in many of the interviews is a sense of growing degree of commitment by the associations to the joint JET endeavours.

The performance enhancements to the JET facilities have allowed for making a major contribution to the consolidation of the scientific basis for the Next Step/ITER, in parallel with the work on the devices in the laboratories of the Associations. JET is an asset to the European programme as the only fusion device capable of operating with Deuterium and Tritium. The results obtained during FP6 have advanced the understanding of confinement, heating, fuelling, exhaust physics and plasma control, as well as associated technologies. This has resulted in further consolidation of the scientific basis for ITER construction and operation and the development of auxiliary systems, the development of improved concepts for the long term optimisation of fusion reactors and improvements in the fundamental understanding of fusion plasmas. The programme has also continued the research into fusion physics and technology, including study and evaluation of magnetic confinement formulas.

Structured R&D activities in fusion technology have been performed within the framework of EFDA, in particular involved activities with the goal of demonstrating the feasibility of a reactor-relevant, burning plasma. The activities have also addressed feasibility issues of a Fusion Power Plant (DEMO). These activities have been complemented and guided by system studies on power plant concepts (Power Plant Conceptual Studies) with emphasis on safety and environmental issues and socio-economic aspects of fusion to demonstrate the potential benefit of fusion power and to improve public perception.

The work in the area of Next Step fusion technology within the EFDA frame has resulted in the development and validation of key technologies such as superconducting magnets, vacuum vessel, blanket, divertor and shielding, heating and current drive systems, fuel cycle, diagnostics. Materials studies have been undertaken aimed at the definition of a fusion reactor reference material with reduced activation; the development of alternative advanced materials; and the definition of materials tests means. The engineering design of a 14MeV neutron irradiation facility has been started within the international co-operation for IFMIF.

The programme has increased the Next Step activities, which were directed to participating in ITER construction, in the second half of 2005. The activities have included studies to prepare the European site of Cadarache and preparations for the participation of European industry in ITER including technological developments related to superconducting magnets, vacuum vessel, plasma facing components and divertor, materials, fuel cycle and tritium technologies, heating and current drive systems, and diagnostics.

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The Wendelstein 7-X.Stellarator construction project has been thoroughly reviewed in 2003 and corrective actions in effort, recruitment, management and industrial relations has been implemented. The outlook for the project is positive and despite a significant delay a review by the Helmholtz Association in 2006 has deemed that the strategic value of the Stellarator is retained.

The programme has included a growing number of activities to develop human resources and mobility, in particular offering training to fusion scientists and engineers and assisting fellows to re-establish themselves in their country of nationality, supported by fellowships and grants.

### **6.3 Quality**

The evaluation of quality of the research has been based on the internal assessments in the monitoring reports as evidenced in the reporting at the CCE-FU level and from the personal assessments obtained in the interviews with key actors and stakeholders with a relevant scientific background (peer review principle). The evaluation has been supplemented by bibliometric analysis in selected areas where benchmarking to analogous scientific endeavours could be made. As discussed in Annex A, section 5.1 publication in reputed scientific journals is important for the exchange of knowledge and ideas and it is generally recognised as an indicator of scientific activity, output and quality. It is also important for the career prospects of young scientists.

Observations: The annual reports and the monitoring reports show that the level of publications is comparable to other fields with a combination of science and engineering. There is a tendency to use publication in conference proceedings more often than periodic science journals. The interviews indicated that the local scientific leaders were aware of this and have encouraged the staff to publish more in regular journals. Bibliometric benchmarking of the publication activities is rarely pursued by the associations visited during the evaluation.

### **6.4 Contribution to Community policy**

The Fusion Programme in FP6 in itself represents a significant Community policy initiative with an obvious bearing on the long-term energy policy of Europe. Associated with this is the long-term competitiveness of the European nuclear energy industry. This will be evaluated via a study of the assessments of the FP6 Fusion Programme in high-level committees like the STC and AGE.

Observations: The Fusion Programme is mission-oriented and focused on the long-term goal of harnessing fusion as a new, sustainable and abundant energy source. To achieve this goal a suite of new technologies have to be developed, ranging from high power electronics to materials that function under extreme conditions of energy flux and radiation load. This has resulted in a spectrum of spin-offs to other branches of science and industry, like remote handling systems, semiconductor manufacturing, plasma

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etching, lithography, ion implantation and plasma displays. Industrial relations and transfer of technology are a strategic concern and effort in the programme, and steps have been taken to ensure a continuing dialogue with industry both at the strategic level and at the operational level. Experience during FP6 has shown that the relations interaction, technology transfer and knowledge interchange with industry are more effective in cases where long-term partnerships have been developed.

### **6.5 European Research Area**

The evaluation has addressed the development of the organisation patterns of the Fusion Programme during FP6. The Fusion Programme has been a manifestation of the “European Research Area Concept” even before it became a practical political goal. The use of contracts of association and Joint Undertakings has a long history in fusion. The lessons learned from the development EFDA, F4E and the closer collaboration in clusters of association contain experience of general use in fields with a less structured European pattern of cooperation. They are of course also useful for the development of the quality and performance of the Fusion Programme itself.

Observations: The development of the Fusion Programme during FP6 has in many ways strengthened its role as a pioneer in the development of the ERA concept. This is manifested by (1) the clear trend of programmatic integration of the association activities within the EFDA framework; (2) the joint exploitation of JET; (3) the EFDA technology programme and (4) the preparation of the European participation in ITER. The experience from the JET exploitation has opened a new and successful way to elaborate and execute a research programme. The result has been the involvement of a substantially larger number of researchers bringing new ideas, skills and experience to the collaboration. A planning process with a structured dialogue has been developed, which leads to focused programs for the campaigns. The exploitation of JET is organised in 7 different task forces with participation from many different associations. The process has evolved over the years and has lead to a new culture of collaboration. The interviews showed that the participants valued this new mode of operation for the JET exploitation. It has resulted in consensus and commitments towards the common goal and has strengthened the integration of the programme both at the strategic level and at the operational level. It has also furthered a common, effective culture for project work. Some judge the procedures as cumbersome, but at the same time also stimulating and effective.

The result has been that the programme goals have to an increasing degree penetrated into the activities of the associations. They have lead to more cooperation and common use of the different facilities available across Europe and prepared the associations for the formation of consortia to execute ITER contracts.

## **6.6 Impact on EU research capacity and leadership**

The evaluation of this has been done via the case study approach combined with assessment of the annual reports and the monitoring reports.

Observations: The unique and long-term nature of the Fusion Programme acts as a light house in the European science landscape. ITER in Europe has magnified the impact and will attract new talent in the years to come. This is already evidenced at the student level by the enrolment in fusion physics courses e.g. in Munich.

The programme has a long track-record of contributions to the knowledge base through e.g. scientific papers, development of new techniques, training of researchers and increases in researcher numbers. In this sense it has contributed to the broader Lisbon objectives and has helped, via the associations, to promote industry spin-offs, education and training, and regional developments in new member countries. The industrial spin-offs are spurred by the transfer of advanced technologies developed in the programme. Examples of this are discussed in Annex A, section 4.

## **6.7 Human resources**

The evaluation has examined the initiatives at programme level to stimulate mobility, training, gender balance and recruitment both within the programme and to the outside scientific communities. The impact of these measures is gauged via the case studies.

Observations: The survey of staff in 2004 estimated that with the addition of the new Member States, the EURATOM Fusion Programme overall has a rather stable staff basis of about 2000 professionals and about 1700 support staff. The study also showed that during the preceding three years there was a net increment of about 5.5 % of new staff per year. However, the balance of staff competence is changing, as recent recruitments have been mainly in the area of physics. The number of engineers with specialised experience in fusion technologies and machine design and assembly has been limited also in the past. This can explain some of the apparent difficulty in staffing new projects. Some of the new associations express the concern that the increased mobility may cause an unwanted “brain drain” from less favoured regions.

The European Fusion Training Scheme (EFTS) was launched with a call for proposals in October 2005 aimed at increasing the number of staff with fusion-specific engineering skills. In addition, the training of researchers at post doctoral level is supported by the EURATOM Fellowship scheme, which supports individual researchers carrying out well-defined research and training projects, in an area relevant to the Fusion Programme, for up to two years. It is the general view from the interviews that these measures are adequate and have been well accepted by the associations. Their use is growing. The specific initiatives in this area are discussed in more detail in Annex A, section 7.

## **7 Conclusions**

The European Fusion Programme has fulfilled the objectives of FP6. The programme has made decisive progress towards the realisation of the Next Step, ITER, in the framework of international cooperation. The political and organisational framework is now in place and ITER will be constructed in Europe. ITER will be able to demonstrate the scientific and technological feasibility of fusion energy production based on the tokamak principle.

The Fusion Programme has operated as a fully integrated R&D programme within the spirit of the European Research Area. The programme has concentrated on the goals set out in the programme decision thus (1) advancing the physics and technical basis for the construction and exploitation of ITER, (2) on developing several device concepts which may, over the longer term, offer the potential for improved fusion power plants, and (3) on developing the technological basis for the construction of a DEMO fusion power plant. DEMO would be constructed subsequently to ITER and would demonstrate the capability of fusion for electricity production.

The programme has been managed effectively and efficiently while coping with uncertainties due to the hiatus in the ITER decision process. During FP6 the programme has developed a new management structure suited to focus on and interact with the ITER project. The collaboration among the associations has increased supported by the EFDA managerial system and new training and mobility schemes.

The JET machine has been operated successfully in the new EFDA regime. The exploitation has taken advantage of the recent improvements. Research has been continued into fusion physics and technology, including: study and evaluation of magnetic confinement formulas with, in particular, the continuation of the construction of the Wendelstein 7-X Stellarator and operation of the existing installations in the EURATOM associations. The programme has executed the planned coordinated activities regarding technological research, in particular research into materials for fusion.

The results have confirmed the leading position of the European programme and contributed significantly to the knowledge base ITER construction and operation as well as the design of a demonstration reactor, DEMO.

At the same time the programme has entered a new regime. It has become more complex to manage the global, European and national efforts. The growing need for a large, new energy source has raised the outside expectations and desires for fast-track scenarios, which cannot be delivered within the current budget envelopes.

ITER should given the highest priority to prove, without delay, the feasibility of a tokamak fusion energy producing reactor. The European Fusion Energy Research Programme has a special responsibility as the lead partner to secure the success of the ITER endeavour. This will require a continued, very competent and focused effort at all levels of management of the programme.

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### 8 Abbreviations and Definitions

Abbreviation	Explanation
AGE	Advisory Group on Energy
ASDEX	Axially Symmetric Divertor EXperiment
CCE-FU	Consultative Committee for the EURATOM Specific Research and Training Programme in the Field of Nuclear Energy (Fusion)
CERN	European Organization for Nuclear Research
CIEL	“composants internes et limiteurs” project at TORE-SUPRA
CSU	Close Support Unit
DEMO	Demonstration Power Plant
DG Research (RTD)	Directorate-General for Research
EFDA	European Fusion Development Agreement
EFTS	European Fusion Training Scheme
EIROFORUM	European International Research Organisations Forum
EP1	Enhancement Programme 1
EP2	Enhancement Programme 2
ERA	European Research Area
ERA-Net	Networking and Integration of National and Regional Programmes
EURATOM	European Atomic Energy Community
EURATOM STC	EURATOM Scientific and Technical Committees
Eurofer	European Confederation of Iron and Steel Industries
EVEDA	Engineering Validation Engineering Design Activities
EXTRAP-TR2	Medium-sized reversed-field pinch device at KTH in Stockholm
EXTREMAT	Materials for Extreme Environments
F4E	European Joint Undertaking for ITER and the Development of Fusion Energy
FP5	5 <sup>th</sup> EURATOM Framework Programme
FP6	6 <sup>th</sup> EURATOM (Research) Framework Programme
FP7	7 <sup>th</sup> EURATOM Framework Programme
FTU	Frascati Tokamak Upgrade
IFMIF	International Fusion Materials Irradiation Facility
IPP	Max Planck Institute für Plasmaphysik
ITER	International Thermonuclear Experimental Reactor
JET	Joint European Torus
RTD	Research and Technology Directorate
SET-Plan	European Strategic Energy Technology Plan
STAC	Science and Technology Advisory Committee
STC	Euratom Science and Technology Committee

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Abbreviation	Explanation
TCV	Tokamak à Configuration Variable
TEXTOR	Tokamak Experiment for Technology Oriented Research
ToR	Terms of Reference
TORE-SUPRA	Superconducting Tokamak at Cadarache

