Socio-economic dimensions of Fusion Energy

Thursday September 19th from 9.30 to 17.00

This meeting has three main objectives:

- Provide a showcase for existing European socio-economic research on fusion (SERF), highlighting the broad range of investigations and the key findings to date.
- Facilitate exchanges between researchers working in these areas.
- Explore the potential for collaboration and cross-fertilisation within Europe and beyond in future research.

The meeting has been designed to focus on practical applications of these areas of research, and to be of interest to a wide audience within the fusion community.

This is a PUBLIC event opened to ISFNT attendees

Local organizing committee:

Ana Prades
ana.prades@ciemat.es

GOBIERNO DE ESPAÑA · MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD · Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

EFDA EUROPEAN FUSION DEVELOPMENT AGREEMENT

Socio-economic dimensions of Fusion Energy

Thursday September 19th from 9.30 to 17.00

9.30: Welcome and details on the satellite meeting
Dr. Ana Prades (Local Organizing Committee)

10.00: Overview of the EFDA Socio-Economic Research on Fusion (SERF) Programme
Dr. Magdalena Gadomska (EFDA Responsible Officer)

10.30 – 11.00: Coffee break

11. 00 – 13.00 : Overview of SOCIAL RESEARCH ON FUSION
Dr. Ana Prades (CIEMAT) , Prof. Tom Horlick-Jones (Cardiff University), and Dr. Gaston Meskens (SCK-CEN),

11.00 -11.30: Lay understanding and reasoning about fusion energy (Ana Prades , CIEMAT & Tom Horlick-Jones, Cardiff University)

11.30 – 12.00: Dialogues with stakeholders working at the research-policy interface (Gaston Meskens, SCK-CEN)

12.00 – 12.30: Public discourses on fusion energy: Media coverage of nuclear & fusion energy in Europe before and after Fukushima (Ana Horta, Luisa Schmidt, and Sergio Pereira (ICS/UL-IST)

12.30 – 13.00: Discussion and links to the Economic Research on Fusion

13.00 – 14.00: Lunch

14.15 – 16.00: Overview of ECONOMIC RESEARCH ON FUSION
Dr. Helena Cabal & Dr. Yolanda Lechon (CIEMAT)

14.15- 14.45: Research in Fusion energy economics (Chiara Bustreo, ENEA_RFX)
14.45 – 15. 15: Modelling future Energy Scenarios: EFDA TIMES (Helena Cabal & Yolanda Lechon, CIEMAT)

15.15 – 15.45: Discussion

16.00 – 17.00: Round Table Discussion: collaborative options and new ideas
- Implications of socio-economic research for PI/PR work.
- Future directions in SERF.

Chair: Dr. Gaston Meskens (SCK-CEN)
Rapporteurs: Prof. Tom Horlick-Jones (CU) & Dr. Ana Prades (CIEMAT)

11th International Symposium on Fusion Nuclear Technology
Satellite meeting on Socio-Economic Dimensions of Fusion Energy

Making Sense of Fusion:
Research into Lay Perception and Reasoning, Learning and Communication Processes

Ana Prades[1] and **Tom Horlick-Jones**[2]
1. CIEMAT-CISOT 2. Cardiff University

GOBIERNO DE ESPAÑA | MINISTERIO DE CIENCIA E INNOVACIÓN | Ciemat CISOT Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas | Centro de Investigación Socio-técnica de Barcelona | CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD | E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL | EFDA EUROPEAN FUSION DEVELOPMENT AGREEMENT

Overview

- Present some themes in the SERF programme, broadly concerned with lay understanding of fusion
- Make clear the contrasting perspectives and approaches that have been adopted to investigate this area
- Set out the main findings to date, including their practical implications

Why research lay understanding of fusion?

- Scholarly interests
- Promoting public understanding of fusion science and technology
- Addressing possible difficulties associated with the public acceptability of new technologies

The research challenge

- **Comprehensive literature review (Prades *et al*, 2007)**
  - Largely restricted to Europe, SERF studies, ITER siting
  - Some Japanese work; US activity restricted to educational initiatives.

- **Findings**
  - Very limited awareness, lack of knowledge
  - Seen as abstract, except in siting studies
  - Unfamiliar technology: an investment opportunity? Socially acceptable?
  - Role of associations with military use of nuclear technologies, and with the fission program

- **A research agenda**
  - How to deal with such low levels of knowledge?
  - How to deal with the abstract and unfamiliar?
  - What is the nature of lay reasoning about fusion?
  - Not simply a matter of ‘filling up’ lay citizens’ heads with knowledge: c*itizens need to engage with information about fusion technology. Providing such information in a suitably balanced way* is a non-trivial problem, and indeed a research task in itself
  - → Do lay perceptions change as they learn more about the technology and associated issues? *The need to investigate the dynamics of the learning process*

SERF research to be considered in this session

	SCK-CEN	CIEMAT- Cardiff University	IPPLM
Context	ITER Sitting decision and public opinion	Abstract and unfamiliar fusion technology: reasoning process	
Method	Groups Focus groups	Hybrid groups	Quasi experimental
Samples	Lay citizens Local communities	General public demographic sampling	Students
Findings & implications Application	Key issues emerging from the research and practical implications for learning and communication process: **Fusion EXPO evaluation**		

→ The ITER Siting Decision and Public Opinion (Lakshmi Chayapathi & Erik Laes, PISA/SCK-CEN)
→ Lay attitudes, scientific information and lay reasoning about fusion (Magdalena Gadomska, IPPLM)
→ Lay learning and reasoning about fusion energy (Ana Prades & Tom Horlick-Jones, CIEMAT/ CU)
→ Evaluating the Fusion Expo (Ana Prades & Tom Horlick-Jones, CIEMAT/ CU)

1. ITER and public opinion (SCK-CEN)

- **Method**:
  - Understanding public perception of the ITER siting decision in Cadarache using focus groups (orthodox application of this method)

- **Main findings:**
  - Largely uninformed public, fusion as distant and hypothetical.
  - The research nature of ITER contributes to a basic levels of support.
  - Current absence of controversies is not guaranteed for all future stages
  - Lay demand for more transparent and interactive, communication efforts with diversified sources of information. Trusted and independent sources needed, not the French nuclear sector
  - Lay request for active and long-lasting role of local populations. But no clear expectations found regarding potential public involvement processes. NB lack of participatory tradition in France, but recently evolution towards more inclusive forms of governance.
  - It is essential to engage stakeholders and the public in decision making-practices, and to cover a wide range of issues and perspectives that are not necessarily directly concerned with ITER, but which are clearly associated with it by the civil society.

2. Lay attitudes towards fusion: a quasi-experimental study of the impact of scientific information (IPPLM)

Method

- Quasi-experimental approach: Five groups of students read five versions of informative material (prepared by fusion researchers) - groups' knowledge and judgments were confronted among them and with those of a control group which was not taken through a learning process

Main Findings

- Reasoning based on lack of knowledge is predominantly risk perception-driven.
- The learning process is informed by both risk and benefits perceptions, with pre-existing attitudes playing a role in re-structuring new knowledge.
- Uncertainties and scientific disputes play a key role: the dispute-narrative reinforces the affective nature of perception.
- Reactions to technological risks have mixed cognitive and affective nature and this is so even in well-informed subjects.

3. Lay learning and reasoning processes (Ciemat/ Cardiff University)

- **Method:**
  - Hybrid: Reconvened focus groups, Stimulus materials, Facilitation devices, Diaries and exercises. Process that allows lay groups to assimilate information in their own terms. Quasi-naturalistic ordinary language discourse.

- **Main findings (illustrations to follow)**
  - Awareness of fusion and the role of the nuclear brand
  - Modes of reasoning & use of interpretative resources
  - Information materials about fusion
  - The nature of acceptability of fusion
  - Social accounting practices: the structure of pro-nuclear accounts

A. Awareness of fusion and the role of the nuclear brand

MOD. Have you heard of nuclear fusion energy?
F1. Name it
F2. Exactly
M1. I think it's something **like nuclear energy, but not dangerous, is that the idea?**
M3. Yes, I've heard of it...
MOD. It doesn't ring too many bells?
All ... it rings bells but no...
(Lengthy silence)

M2 The moment will come, we won't live to see it, but later generations will for sure, what we have is all being used up and that's been demonstrated, and so for all ...this isn't ... isn't a sea ... what I mean is ... **what's happening is that it's reminiscent of atom ... and naturally, that reminds us of ....**

F2. **It smacks of disease ...it's that clear**

M2. **like Chernobyl, right?**

F3. **Yes**.

Group 4 – Spain [Over 40; ABC]

F3. No. As soon as you hear the word nuclear anyway, **it sends shivers down your spine**

Mod. Why's that?

F3. I don't know. It's just...

Mod Let's sort this out then, this nuclear business. I mean what ...

F: Is it safe, is it dangerous, you don't know.

Mod No, no, but aside from that, why do you think you would feel that it's frightening in some way?

F: Because probably I don't know enough about it.

Mod Yeah, what does it make you think of?

F: I don't know, just ...

F: A bomb.

F: Bombs and ...

F: Yeah, bomb, yeah.

Mod Bombs and nasty stuff generally.

F: Yeah, nasty stuff doesn't it.

F: Was it Cumberland where the, or up that way anyway, where there was a big hooha several years ago because they thought it was **causing cancer in the children.**

F: Yeah.

F: There was a nuclear plant up there, you know, and they felt that they had such a high ...

F: It's still there isn't it?

F: You know, a high total of children's cancers....

Group F – UK [Over 40; CDE]

B. Modes of reasoning and use of interpretative resources

- **Structural calculative** (IF it is in France it is SAFE)

Group 3- Spain (18-25; CDE):
M2. And would this be dangerous? ... Because, naturally, if it is very good energy ... but ... the problem is that it's dangerous, so ... even if it's very efficient, if it's dangerous then it's not so good.
M3. **If it was dangerous they wouldn't have it in France I think.** They'd have it in another country in the third world. Like they've always done with atomic tests and so on, they've done them in the Pacific ….or in places like that…
M2. In the United States they probably did them...
M3. **Yes, but the European Union ... I don't know ... I'd say that if it's in France...**

❑ **Grounded in technical knowledge** (“mechanisms” that makes it SAFE)

Group 5- Spain (26-4’; CDE):

M3. It’s like, for example, with this kind of energy, from what I can see here, there can’t be more accidents like Chernobyl; that was fission, and that is reactions followed by reactions, which can go out of control ... that's what it says, here… when you see that there could be ... pum… you turn it off and that’s it ... **it’s a small safety mechanism …unlike with other types of nuclear energy.**

F3. You know, I imagine that when they build nuclear stations they don't think in terms of there being this failure...

M3. No of course, in the old nuclear stations if there is this failure it can’t be avoided.

F2. Here you can switch it off.

M3. Here **you can switch it off,** if you have any doubts … disconnect and end of story.

Main insights on lay understanding in UK and Spain

- Significant **shared characteristics and some differences**

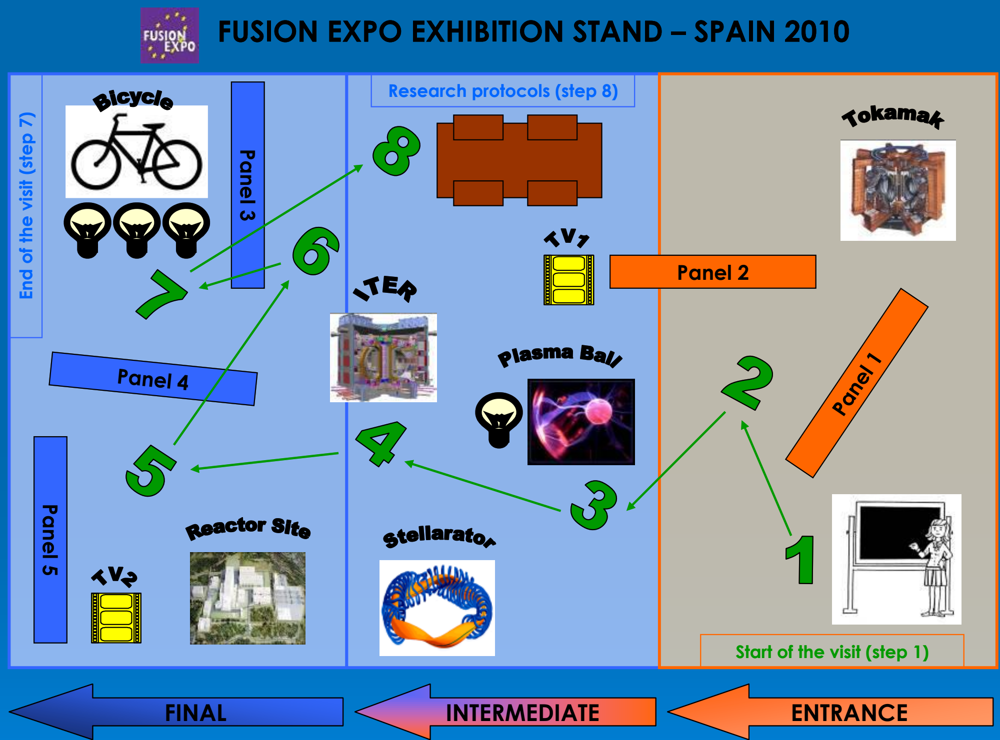
Shared:

- Limited awareness about fusion
- Nuclear brand: key device (fear; pragmatism; etc.)
- Relevant role of structural calculative practices (analogies)
- Difficulties to grasp technical details
- Role of shared interpretative resources (The Simpsons)
- Fusion and "messing with nature"
- Moderate environmentalist discourse

Differences:

- The "new" brand: specifically Spanish reason practice
- Vested interest of scientific researchers as a UK concern
- Socio-demographic variables (indeed with caution on the sample size): gender as a relevant dimension in the UK and age in Spain.

Application of CIEMAT/Cardiff approach: Pilot multi-method study to evaluate the Fusion EXPO



The Catalan Museum of Science and Technology (BCN) hosted the Expo during March-May 2010 (http://mnatec.cat)

Key findings from CIEMAT/Cardiff evaluation of the Fusion EXPO

- EXPO is poor at promoting assimilation of technical knowledge about fusion (*focus groups*).
- EXPO is moderately successful in promoting a view of fusion as an attractive potential source of energy (*questionnaire, drawings and photo diary, focus groups)*
- Support for fusion is not directly related to assimilation of technical knowledge: detailed technical understanding is not a pre-condition for support for the technology.
- Support for fusion as an energy source is not achieved by an exhibition which portrays fusion in wholly positive terms.
- Risk of the support being vulnerable to change in the light of information easily available on Internet: possible serious implications for trust in the fusion R&D community (*photo diary, drawings, and particularly focus groups*).

- Effectiveness of the **evaluation methods:** suitability of short questionnaires and focus groups and significant promise of video research (*video data*)

Discussion

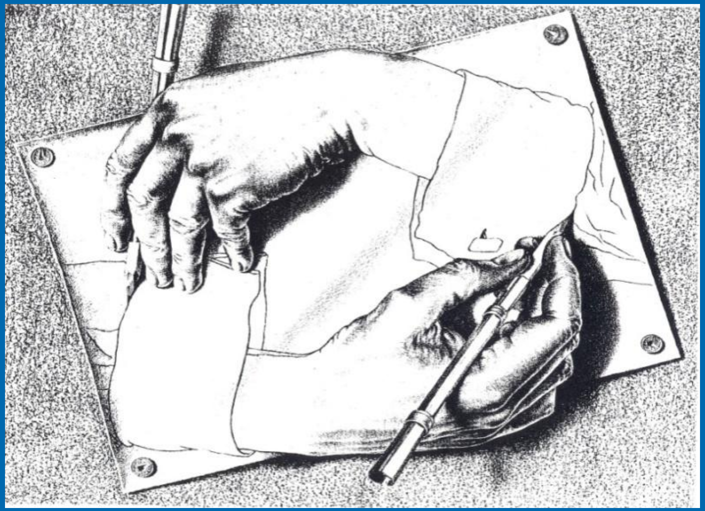
a) on contrasting methodological approaches

b) on key findings and practical implications

Contrasting approaches - 1

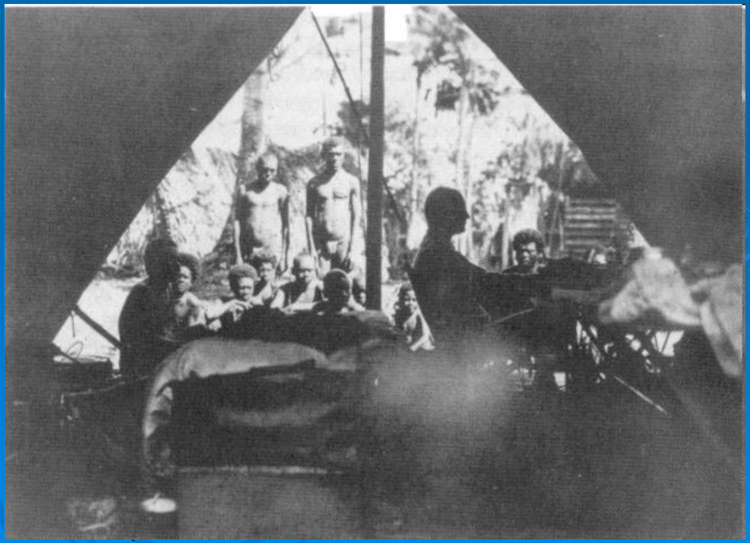
➢ Psychologies/Sociologies: spectrum of underlying conceptions of human nature

- Individual cognitive processing shaped by cultural biases
- Social beings with individual views best elicited through social interaction.
- Language-performing social entities drawing upon socially-shared resources. Real-world reasoning socially constituted.



➢ Quasi-experimental/ social research/ ethnographic

- 'Laboratory'' approach to investigate knowledge processing
- Research to investigate knowledge environment created for local people by information initiatives and media coverage. Interviews/discussions with locals
- Observing performances of indigenous language-games



Contrasting approaches - 2

➢ Use of groups

- Individualistic processes in group settings
- Orthodox focus groups: a balance between interviews and discussions with sample groups. NB limits on validity because of small samples
- Hybrid groups that seek to elicit naturalistic performances. Concentration on socially-shared resources. Individual participants as vehicles for socially-shared ways of acting and talking. Enhanced validity

b) Key findings and overall conclusions for future practice

- There are changes of reasoning practices as recipients learn more about the technology, but differences over exactly the nature of the changes.

- There is a need to embrace and engage with multiple sources of knowledge and uncertainty (*just good news is not good*):
  - How to deal with disputes within the scientific community? (IPPLM)
  - Significant implications for the production of information materials about fusion.

- Support for fusion is not directly related to assimilation of technical knowledge. Technical understanding is not a pre-condition for support. There is a need for lay understanding to include wider social implications of fusion technology.

- Need for engagement with lay publics (SCK-CEN and Ciemat/Cardiff research).

SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

EFDA
EUROPEAN FUSION DEVELOPMENT AGREEMENT

Dialogues with stakeholders working at the research-policy interface

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Satellite Meeting on the Socio-economic dimensions of Fusion Energy
Barcelona, 19th September 2013

Dialogues with stakeholders working at the research-policy interface
Structure

Intro 1 Context: the ISAF Project

2 Earlier SCK•CEN research in the context of EFDA-SERF

Dialogues 1 Scoping Study 2010 (ISAF Part 1)

2 Modelling Assessment Workshop (ISAF Part 2)

3 Informed civil society opinions on fusion energy R&D (ISAF Part 3)

Conclusion 1 A reflection on the science and politics of scientific foresight

2 Constructing a credible story of societal relevance for fusion research

Intro 1

Dialogues with stakeholders working at the research-policy interface
Context: the ISAF project

- The aim of the project is to perform a policy-supportive Integrated Sustainability Assessment of energy systems with a focus on including Fusion as an energy (policy) option (acronym ISAF).
- The ISAF exercise investigates the usability of various decision support methodologies, procedures, structures and tools, including energy scenarios development, for a 'sustainable energy policy'.
- With the engagement of reference stakeholders' groups, it also provides a platform for a reflective and discursive interaction among researchers and policy makers that now tend to belong to rather separated worlds: the one dealing with fusion energy, and the other dealing with other energy technologies.

Intro 2

Dialogues with stakeholders working at the research-policy interface
Earlier SCK•CEN research in the context of EFDA-SERF

2002 Sustainability assessment methods for the fusion option : lessons learnt from fission
Part I: Methodology
Part II: Critical evaluation of the concept of external costs
Erik Laes, Gaston Meskens

2006 Twin study

1 Research and guidance on the use of long-term energy scenarios in communication on fusion research
Erik Laes, Gunter Bombaerts, Gaston Meskens

2 The use of energy scenarios in communication on fusion research
Erik Laes, Gunter Bombaerts, Gaston Meskens

The first was theoretical research, the second interactive research, engaging
- EFDA energy scenario modelling experts (interviews)
- secondary school students (focus groups)
- members of the public (Computer Assisted Personal Interviewing)

Intro 2

Dialogues with stakeholders working at the research-policy interface
Earlier SCK•CEN research in the context of EFDA-SERF

2007 Review of impact of communication of the EU ITER siting decision in terms of public opinion
Lakshmi Chayapathi, Erik Laes

2008 Lessons Learned from Public Interaction, Participative Processes and Information/ Communication Strategies in the Context of Big Nuclear Projects: Lessons Learned and Recommendations for Fusion
a collaboration of the Institute of Risk Research (IRR, University of Vienna, Austria) and SCK•CEN (The Belgian Nuclear Research Centre, Mol, Belgium)

2010 Integrated Sustainability Assessment
Gaston Meskens, Jantine Schröder

↘ All reports are available as EFDA-SERF deliverable.

Dialogues 1

Dialogues with stakeholders working at the research-policy interface
Scoping Study 2010 (ISAF Part 1)

aim — To critically study the usability and workability of the concept of sustainable development for fusion (or any other energy technology) to 'rationalise' or 'promote' itself in practical energy policy.

or thus — to inquire into the normative reference base for energy governance research & policy

in practice — the organisation of a reflection group on
"The meaning and the possible use of the concept of sustainable development in the context of energy governance"

steps —
(1) expert selection, invitation and preparation of the background material
(2) reflection group
(3) synthesis, conclusions and recommendations

↘ The reflection group took place in Brussels on 22 November 2010.
↘ The background document and the synthesis report are available as EFDA-SERF deliverable.

Dialogues 1

Dialogues with stakeholders working at the research-policy interface
Scoping Study 2010 (ISAF Part 1) / key findings

- From the discussions two general ideas related to making sense of energy technology assessment in relation to sustainable development emerge: one with regard to reference and one with regard to method:

→ Qualifying a specific technology as '(not) sustainable' sounds like a strategic 'thin rationalisation' of complexity;

A more careful consideration of the use of the concept of sustainable development in relation to technology options is needed in policy appraisal contexts;

→ With respect to modelling, it was agreed that quantitative data 'to make the case for fusion' is needed, but that 'the act of opening up' with the aim to seek deeper understandings and common grounds with respect to the use of the concept of sustainable development as reference is actually the more important joint responsibility of the global community of policy, research, civil society and the private sector.

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Dialogues 2

Dialogues with stakeholders working at the research-policy interface
Modelling Assessment Workshop (ISAF Part 2)

aim	to perform research on the integration of EFDA TIMES modelling in the broader Integrated Sustainability Assessment approach
focus	modelling assessment = inquiring into the 'usability' of modelling in general and of the EFDA-TIMES model in particular as a decision support tool for a long term energy policy
'usability' =	in support of policy, but also as a mediating tool in/for policy
in practice	the organisation of a modelling assessment workshop (one day) with the involvement of EFDA-TIMES model developers, sustainability assessment experts and 'future users' of the model from out of the energy policy world;
steps	(1) expert selection, invitation & preparation of the background material (2) workshop (3) synthesis, conclusions and recommendations

↘ The workshop took place at the ENEA HQ in Rome on 19 September 2012.
↘ The background document and the synthesis report are available as EFDA-SERF deliverable.

Dialogues 2

Dialogues with stakeholders working at the research-policy interface
Modelling Assessment Workshop (ISAF Part 2) / key findings - 1

- The following issues emerged from the discussions as key issues to take into account in modelling research :

1. The use of the concept of sustainable development as the normative reference base for fusion research and for modelling research in particular;
2. The nature and credibility of model input data;
3. The use of 2050 as horizon or tipping point;
4. Performance of simple versus complex models in research and outreach;
5. The meaning of trust, transparency and scientific quality;
6. The policy of using ‘tailor made’ models versus ‘generic’ models;
7. The motivation and usefulness of outreach, participation and cooperation for the ETM team.

Dialogues 2

Dialogues with stakeholders working at the research-policy interface
Modelling Assessment Workshop (ISAF Part 2) / key findings - 2

- The following issues emerged as general points of attention for the future ETM research policy of EFDA:

  the importance of

→ a continuous care for a broad and deliberate conception of modelling input data, criteria and story lines;

→ transparency in modelling as a criterion for scientific quality and credibility;

→ a deliberate use of time horizons in modelling;

→ scientific cooperation in modelling over the importance of using EFDA-TIMES as a communication tool in advocacy for fusion.

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Dialogues 2

Dialogues with stakeholders working at the research-policy interface
Modelling Assessment Workshop (ISAF Part 2) / key findings - 3

- General perception of fusion from informed civil society (other than fusion) to take into account:

→ researchers from the 'other' energy technology world consider fusion as a research activity (and related research policy activity) that could concern them in the context of the allocation of European research funds, but not as an element to take into account in their own research
(they see 2050 as a horizon, while EFDA sees it as a tipping point);

→ policy makers dealing with energy policy are concerned with a medium term perspective (2020 / 2030), driven by current ecological and economical challenges (in a politically globalising but multipolar world) and do not bother about fusion, except when they are concerned with fusion research policy from out of a 'belief' in fusion.

Dialogues 3

Dialogues with stakeholders working at the research-policy interface
Informed civil society opinions on fusion energy R&D (ISAF Part 3)

aim to perform an assessment of opinions on fusion energy R&D among informed civil society

rationale contacts with civil society representatives during previous ISAF research revealed a range of attitudes regarding fusion energy, some of them very negative. They were typically found among actors involved in research and policy related to other energy technology options and among policy makers dealing with environmental protection and sustainable development.

focus informed civil society:

→ comprises relevant actors such as the academic world, various organised interest groups (social, ecological), policy advisory councils and research institutes and think-thanks (= actors who have a specific informed vision on energy governance already themselves);

→ represents (and 'materialises') the connection between the general public on the one hand and political authorities on the other hand.

in practice literature study and interviews, synthesis

Conclusion 1

Dialogues with stakeholders working at the research-policy interface
A reflection on the science and politics of scientific foresight

- Thought experiment

In the following reflection, I propose to see the whole of past, current and future activities under EFDA, being

- power plant physics, technology R&D
- designing and construction of demo fusion plants
- energy (policy) modelling including the fusion option
- outreach (generating political and public support) & fund raising

as a major exercise in 'scientific foresight';

→ an exercise driven by a specific ideological vision, executed not only on paper but also assisted by experimental research.

- From the EFDA website:

"28 countries signed an agreement to work on an energy source for the future. EFDA provides the framework, JET is the shared experiment, Fusion energy is the goal." (www.EFDA.org)

Conclusion 1

Dialogues with stakeholders working at the research-policy interface
A reflection on the science and politics of scientific foresight

- What is foresight?

from http://cordis.europa.eu/foresight/definition.htm

"[...] *Foresight covers activities aiming at thinking, debating, shaping the future*

Thinking *Forecasting, technology assessment, future studies and other forms of foresight try to identify long term trends and thus to guide decision-making.*

Debating *Foresight is a participative process involving different stakeholders.*

Shaping *Foresight aims at identifying possible futures, imagining desirable futures, and defining strategies. Results are generally fed into public decision-making, but they also help participants themselves to develop or adjust their strategy.*

Thinking, debating and shaping the future is even more essential today because the complexity of science, technology and society interrelationships, the limitation of financial resources, the increasing rate of scientific and technological change impose on governments and the actors in the research and innovation system to make choices. [...]"

Conclusion 1

Dialogues with stakeholders working at the research-policy interface
A reflection on the science and politics of scientific foresight

- recent 'horizon 2050' research & advocay initiatives

- The EC 'Energy Roadmap 2050' (Dec 2011)
- The UN 'Sustainable Energy for All' initiative
- Report of the IEA Experts' Group on R&D Priority Setting and Evaluation (2012)
- The WBCSD Report 'The Energy Mix' (May 2012)
- The KPMG Report 'Expect the Unexpected: Building business value in a changing world' (2012)
- the PWC Report '100% renewable electricity - A roadmap to 2050 for Europe and North Africa' (2010)
- The European Renewable Energy Council (EREC) Report 'Rethinking 2050 - A 100% Renewable Energy Vision for the European Union'
- The Shell Scenarios 2050
- The WWF Report '100% Renewables by 2050' (2011)
- The Greenpeace Report 'Energy [r]evolution, A Sustainable Energy Outlook (2010)

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Conclusion 1

Dialogues with stakeholders working at the research-policy interface

A reflection on the science and politics of scientific foresight

? **fusion mentioned in**

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- no - The Shell Scenarios 2050
- no - The WWF Report '100% Renewables by 2050' (2011)
- negative - The Greenpeace Report 'Energy [r]evolution, A Sustainable Energy Outlook (2010) [... 'dead end' energy solutions such as nuclear fusion' ...]

→ the comfort of seeing 2050 as a horizon instead of as a tipping point ...

Conclusion 1

Dialogues with stakeholders working at the research-policy interface
A reflection on the science and politics of scientific foresight

- The aim of scientific foresight:

1 Actors concerned with scientific foresight are not in the first place concerned with the future. As researchers, model developers or users, they primarily seek to justify their actions of today;

2 Rather than telling us what we need, scientific foresight informs us about the consequences of what we want;

1+2 → Scientific foresight, as a mediating tool in policy, cannot make people to transcend 'ideological' visions on the energy future. Rather, on the contrary, scientific foresight is used to support ideological visions on that future.

→ The only meaningful exercise in scientific foresight would be a 'joint' exercise, embedded in a reflexive policy-supportive research practice that also includes qualitative research and involves all relevant stakeholders;

→ Constructing a story of societal relevance for fusion
= Constructing a story of societal relevance for fusion research.

Conclusion 2

Dialogues with stakeholders working at the research-policy interface
Constructing a credible story of societal relevance for fusion research

- Current EFDA-SERF research projects generate key insights that can feed into that story,

  but the story cannot be told by SERF or by the fusion community alone.

Conclusion 2

Dialogues with stakeholders working at the research-policy interface
Constructing a credible story of societal relevance for fusion research

- Constructing a credible story of societal relevance for fusion research would require for EFDA a radical change of vision and commitment in three ways:

Gaston Meskens, gaston.meskens@sckcen.be

Conclusion 2

Dialogues with stakeholders working at the research-policy interface
Constructing a credible story of societal relevance for fusion research

- Constructing a credible story of societal relevance for fusion research would require for EFDA a radical change of vision and commitment in three ways:

1 → EFDA should see SERF as the frame of its activities instead of as a small 'supportive' part of it;

Socio-economic research on fusion should, from a technology assessment perspective, inspire and guide technological R&D and investment

but that research should be participative

While the concern with the general public may be mainly related to risk (due to the 'nuclear label'), the concern with 'informed civil society' is more with the way large R&D budgets are justified in perspective of current challenges in energy governance (many representatives from civil society see fusion research as self-referential and self-confirmative);

The fusion community cannot ask the public (through informed civil society) for trust by asking it to wait until it will be proven (in 2050) that fusion works and that, thus, the large R&D budgets have been well spent.

Gaston Meskens, gaston.meskens@sckcen.be

Conclusion 2

Dialogues with stakeholders working at the research-policy interface
Constructing a credible story of societal relevance for fusion research

- Constructing a credible story of societal relevance for fusion research would require for EFDA a radical change of vision and commitment in three ways:

2 → EFDA should initiate and maintain a public, transdisciplinary and inclusive SERF process (a process of 'intellectual confrontation') related to fusion as an energy option, and this by way of

1 reaching out to informed civil society
and 2 engaging the fusion natural sciences and engineering research community and fusion R&D policy makers in that process;

3 → EFDA, as a major actor in energy governance, should care for integrated energy governance research 'taking into account all energy options' at the European and global level:

to care for =

- advocate the need for,
- contribute to capacity building for
- cooperate in

} integrated energy governance research

Satellite Meeting
Barcelona, 19th September 2013

Media coverage of nuclear and fusion energy in Europe before and after Fukushima

EFDA - Task Agreement WP12-SER-ACIF

Ana Horta, Luísa Schmidt, Sérgio Pereira

Universidade de Lisboa, ICS - Portugal

The project

- This paper presents data from the research project "**Public Discourse on Nuclear Energy before and after Fukushima**" (2012), funded by EFDA through the Task Agreement WP12-SER-ACIF.
- The aim of this task was to analyze public discourse on nuclear fusion and fission energy before and after the nuclear accident in Fukushima on 11th March 2011.

The project

- The task consisted of an **international comparison** of media analysis in:
  - three countries (Germany, Portugal and Spain);
  - and in English language newspapers and magazines aimed at the transnational elite (transnational print media).
- Four teams analyzed each case:
  - **Portuguese**: Luísa Schmidt, Ana Horta, Sérgio Pereira, Carla Oliveira
  - **Spanish**: Ana Prades, Christian Oltra
  - **German**: Isabella Milch, Julia Sieber
  - **Transnational**: Piotr Stankiewicz, Radosław Sojak, Łukasz Afeltowicz.

Introduction

- The role of the **media is crucial in shaping public views** about nuclear accidents, risk perception and risk communication of nuclear power and in constructing its cultural meanings (Perko et al., 2011; Butler et al. 2011).

- Previous EFDA studies have shown that media focus on **fusion energy is very irregular** over long periods of time and seems to be tightly **linked to scientific and technologic breakthroughs** (Borrelli, 2004), or to public expectations about hosting fusion research facilities on national territory - for instance, the candidacy of Vandellós (Spain) for the siting of the ITER research device (Prades et al, 2007).

Method and data

- The research conducted encompasses the coverage, thematic framing, valuation, image construction and impact of Fukushima in media presentation of nuclear and fusion energy:
  - **quantitative** content analysis - to measure the frequency of topics, messages and events presented in the media;
  - exploratory **qualitative** thematic analysis – to provide insights about “thematic codes” presented in media texts and specific meanings related to both fusion and fission.

Sample characterization

- **Fusion energy**
- Germany - articles published in national-based newspapers/magazines between the first quarter of 2010 and the first quarter of 2012;
- Portugal and Spain - articles published in national-based newspapers/magazines between the first quarter of 2008 and the third quarter of 2012;
- Transnational print media – articles published in English language quality newspapers addressing the transnational elite between the first quarter of 2008 and the third quarter of 2012.

- Keywords search: “nuclear fusion”; “nuclear energy”

- **Nuclear energy (fission**)
- Portuguese, Spanish and Transnational print media - articles published by mainstream newspapers and magazines between the first quarter of 2010 and the third quarter of 2012.

- Keyword search: “nuclear energy”

Sample characterization

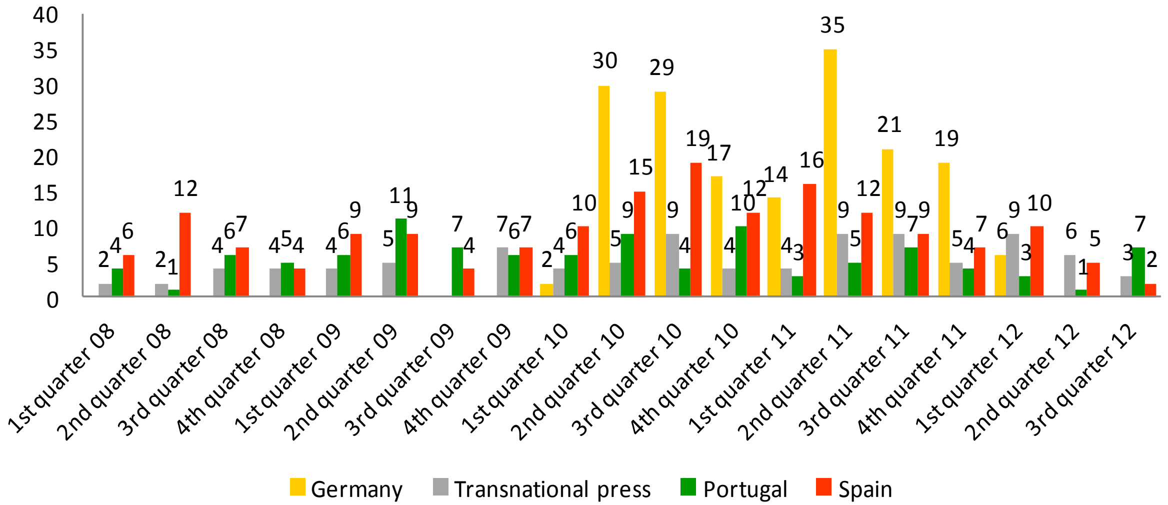
Table 1. ***Number of articles in the sample***

	Germany	Transnational	Portugal	Spain
Fusion	174	95	105	166
Fission	--	569	848	486

Table 2. ***Sampled articles for fusion qualitative content analysis***

Media context	Core subject	Not core subject	Total
Germany	16	4	20
Portugal	11	9	20
Spain	18	6	24
Transnational	11	13	24

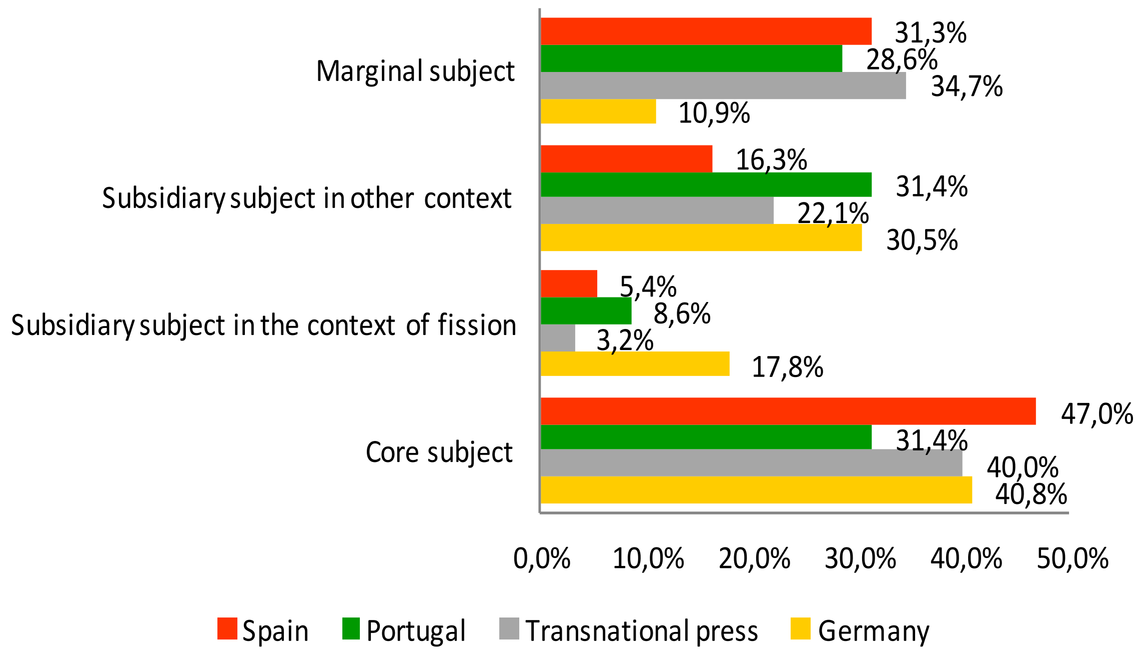
Media coverage of fusion energy



Evolution of the number of articles about fusion energy

- Fusion energy was **more widely covered in Germany** than in any other studied area, especially between the second quarter of 2010 and the forth quarter of 2011.
- The number of articles published by Portuguese and Transnational print media evolves in a similar way throughout the whole period of analysis, always at a low level.
- The amount of articles published by the Spanish press tend to follow more closely the evolution of articles published in Germany from the second quarter of 2010 to the fourth quarter of 2011, although with fewer articles published overall.

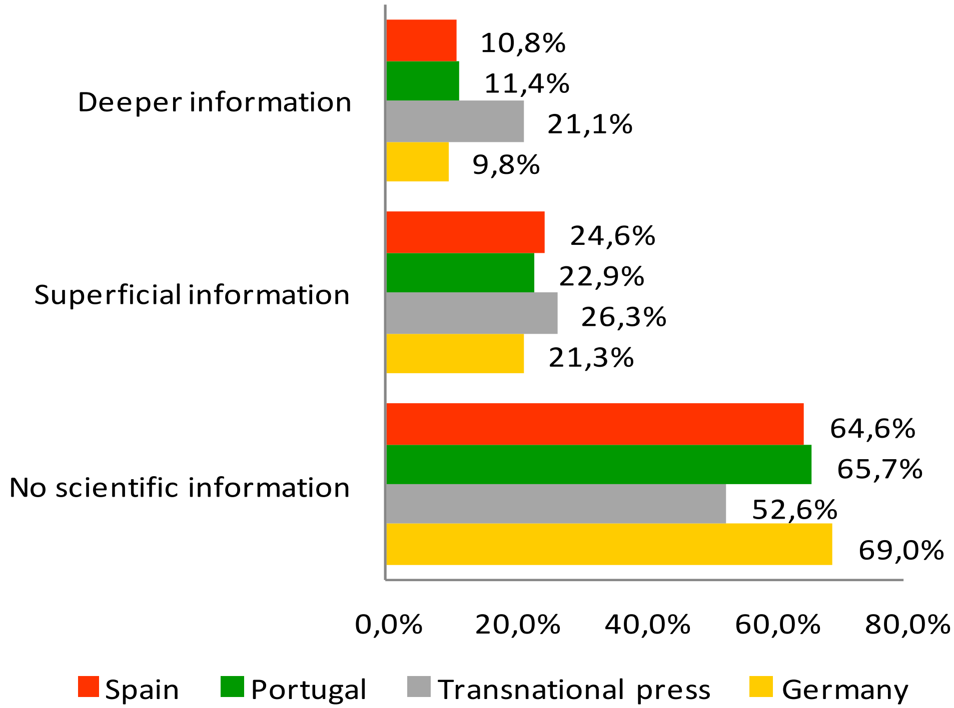
Media coverage of fusion energy



Role of fusion in the fusion related articles

- Fusion is the **core subject** of the articles in less than half of the texts studied. There are few articles that present fusion as a Subsidiary subject in the context of fission.

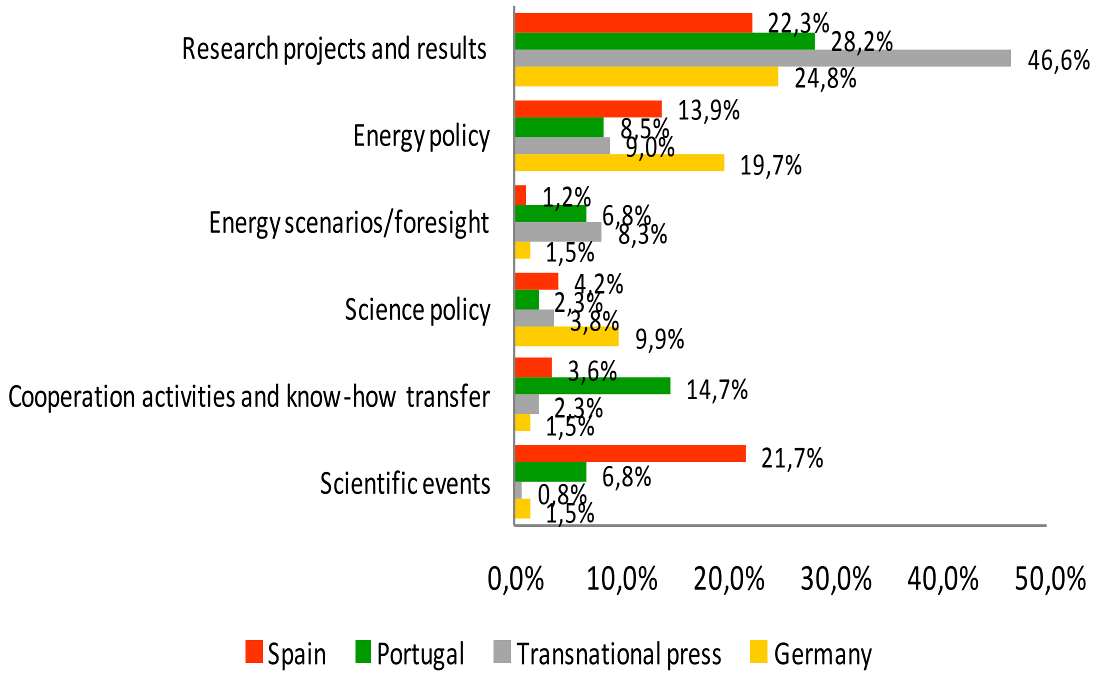
Media coverage of fusion energy



Depth of information about the basic science behind fusion energy

- **In-depth information about fusion is poorly presented**. Most articles do not even mention basic scientific facts about fusion energy.

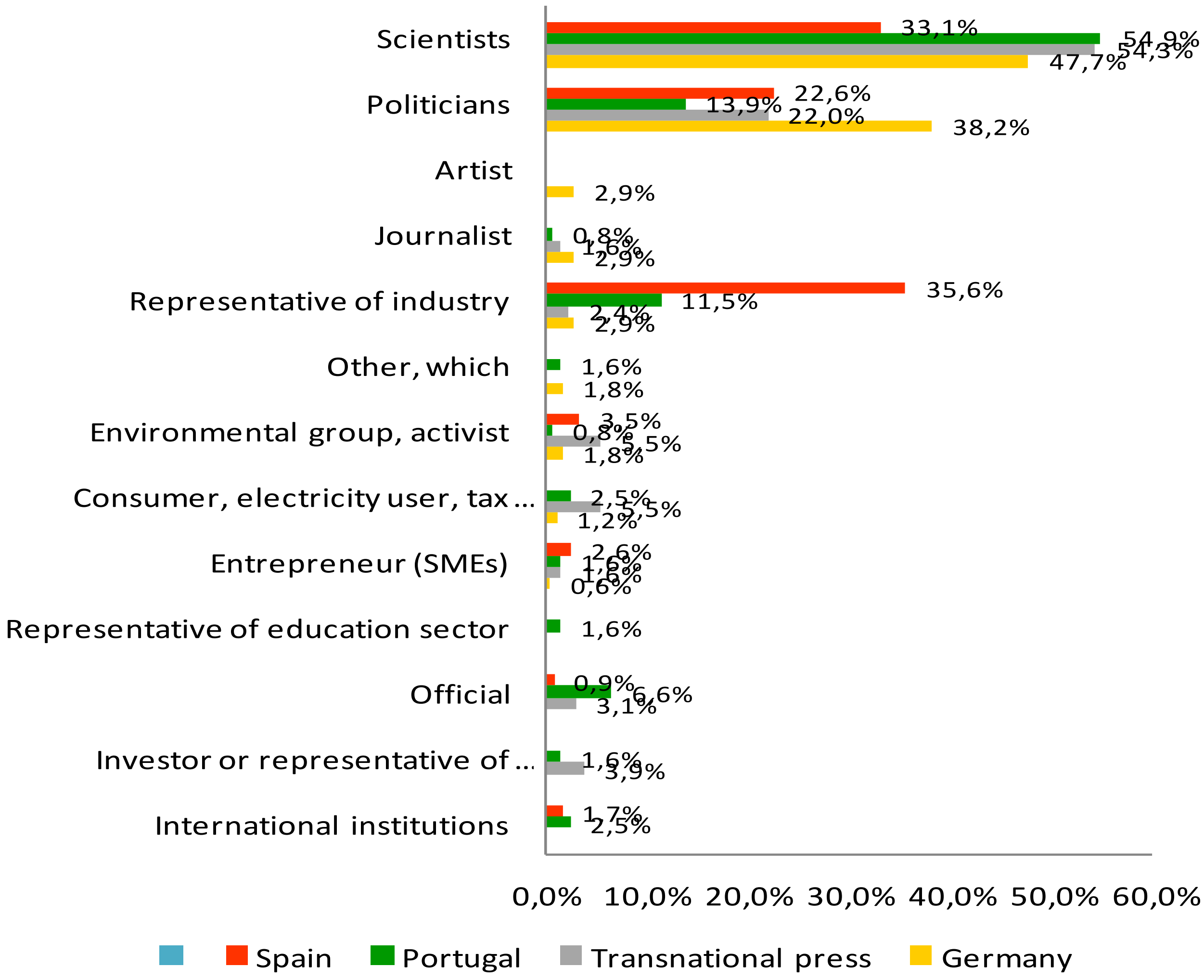
Media coverage of fusion energy



Thematic framing of fusion in articles with fusion energy related content

- Fusion is **strongly linked to scientific and technologic achievements**. In fact, discourse on fusion evolves mainly around research projects, scientific discovery and technologic apparatus, especially in Transnational print media.

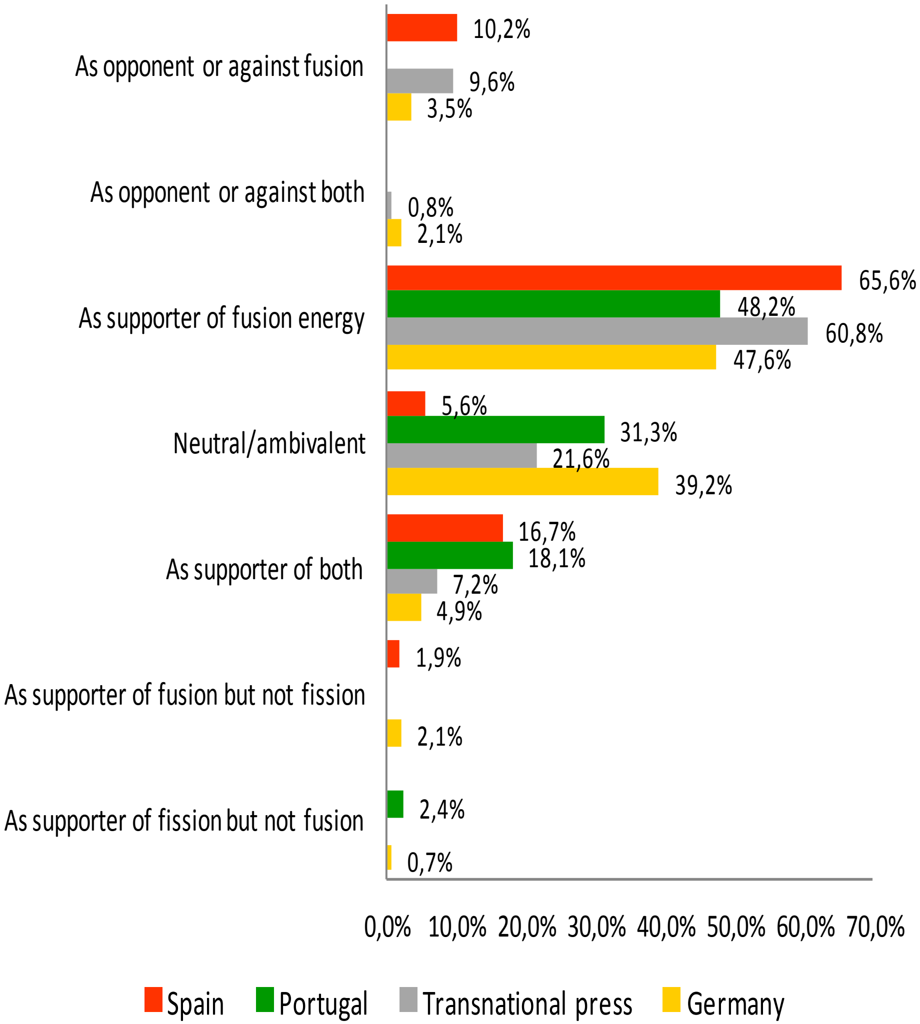
Media coverage of fusion energy



Actors mentioned in the articles about fusion

Scientist are the main actors in the discourse framing of fusion energy in all studied areas, with the exception of Spain, where **representatives of industry** are predominant.

Media coverage of fusion energy



Position manifested by actors about fusion energy

Most actors state their **support to fusion energy**, especially in Spanish and Transnational print media, while those that oppose to it are very few or even absent (Portugal).

Media coverage of fusion energy

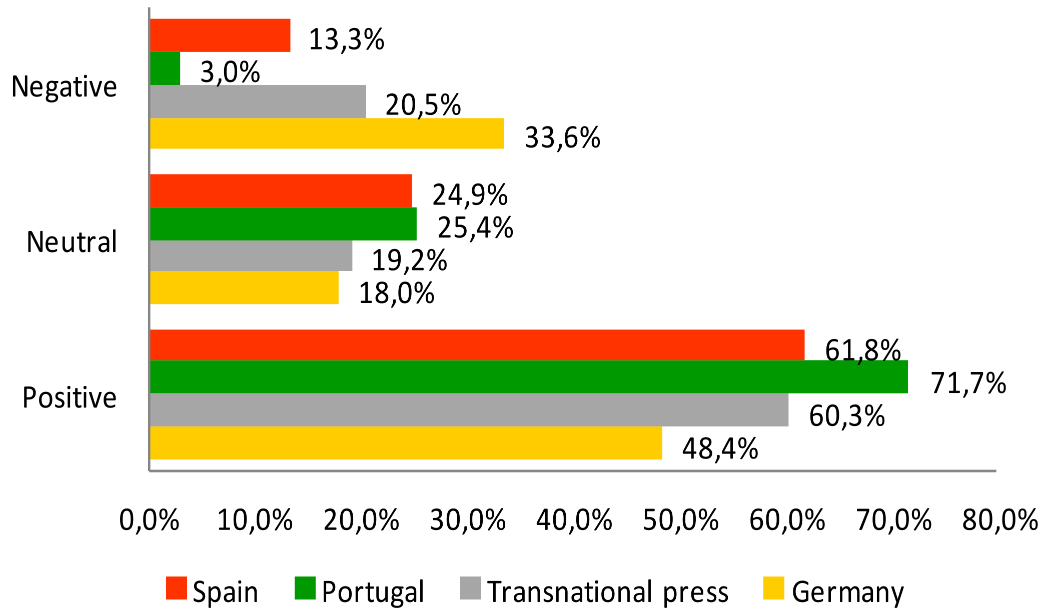
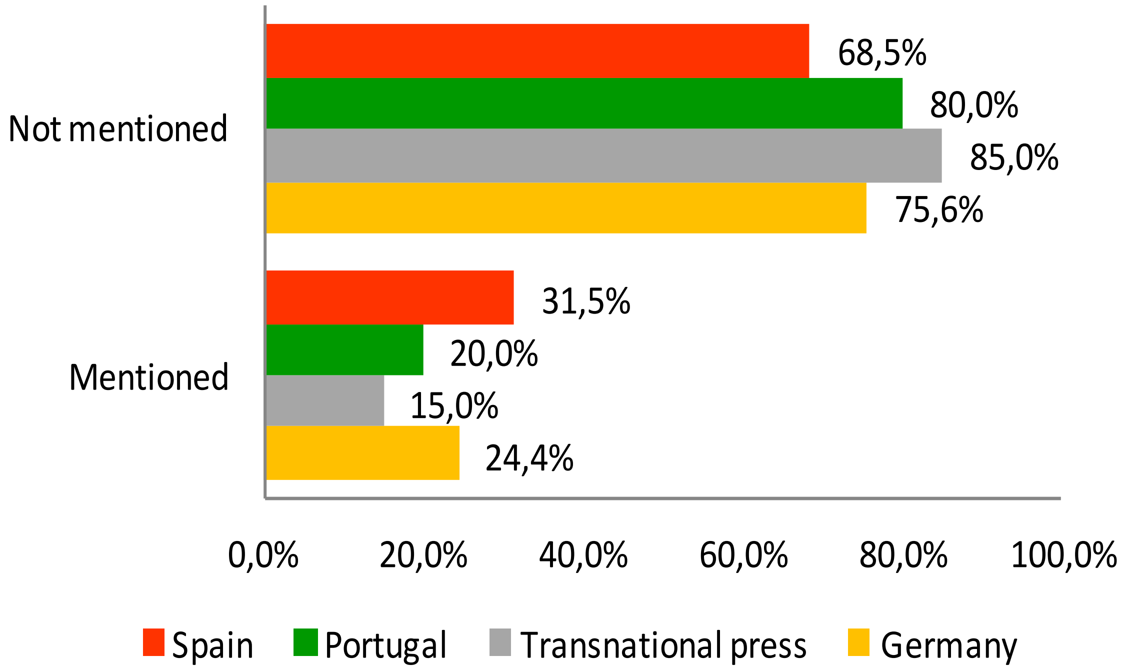


Image of fusion based on various fusion-related costs/benefits in print media with fusion energy related content

- Overall **the image of fusion is clearly positive** in Portuguese, Spanish and Transnational print media whereas in German news it is shaped according to a **stronger divide between positive and negative valuations**, although positive ones prevail.

Media coverage of fusion energy



References to Fukushima accident in the articles with fusion related content

- **Fusion is dissociated from nuclear disasters** such as Fukushima as it is from nuclear energy based on fission. Both these features of media discourse contribute to reinforce a more positive image of fusion energy.

Media coverage of fusion energy

- Comparative in-depth analysis of media discourse revealed some common features to all studied areas:
  - In the current stage of research fusion is presented as a **scientific endeavour** rather than a technical standard for energy production:

    "a crusade to achieve what had eluded thousands of other scientists."
  - The Sun metaphor (artificial replication of fusion energy that occurs within the Sun) is a common and powerful symbolic reference:

    "Fusion is a controlled version of nuclear fusion, the violent process that powers the Sun (...)"

    "The objective is to recreate the energy of the stars, clean, safe and inexhaustible."

Media coverage of fusion energy

- Fusion is clearly portrayed as a **clean, safe and unlimited source of energy**, although scientific arguments are rarely presented in order to support this kind of judgements:

  "Present nuclear power plants generate wastes that stay active for hundreds of years. In comparison, fusion is almost innocuous."

  "much safer, cleaner and producing no CO2."

- There is a **divide in public discourse regarding the technologic feasibility of fusion** - statements presented are either:
  - very optimistic: *"Fusion is not a dream anymore"*
  - cautiously positive: *"The ignition might even be possible. But there is still much to learn"*
  - or even conveyed with irony and ridicule: *"The old joke has it, fusion is the power of the future— and always will be"*

Media coverage of fusion energy

- Economic costs of fusion are mainly associated with the **funding of ITER** (in German, Portuguese and Spanish print media) or with other fusion **large experiment facilities such as NIF** (in Transnational print media). Valuations presented toward costs of fusion research vary mostly from negative to neutral:

  "ITER – the largest and most expensive experiment of all times";

  "Bombs or no bombs, astronomy will start to move from being an observational to an experimental science. At a mere $140m a year, then, the NIF is a snip".

Conclusion

- Media coverage of fusion energy during the period of analysis was **irregular and low level** in all studied areas. Fusion is not a recurrent subject in the media agenda and seems to be reported more as a **scientific curiosity** rather than a topic for broad public debate about its role in current energy policies and future energy scenarios.
- Representations of fusion energy in the media are rooted in the idea that it is **safe, unlimited and clean**. Dissociation from conventional nuclear energy and nuclear accidents plays in favor of a positive image of fusion energy.
- Fusion energy **raises doubts whenever feasibility, investment costs and expectations** about short term connection to the grid are discussed.

Conclusion

- The analysis carried out on public discourse on fusion has allowed us to conclude that **communication on fusion energy is insufficient, fragile and crude.**
- Future communication of fusion energy can benefit from its distinctive features already underlined, mainly with regard to conventional nuclear energy but also by **strengthening the link between scientists and politicians** with regard to the collective value or public interest of fusion energy.
- Fusion implies trans-nationality and cooperation in terms of knowledge and technology, which could be presented as a very positive aspect. While nuclear fission is very much associated with war, **fusion could become associated with a policy of peace and cooperation**.

EFDA
EUROPEAN FUSION DEVELOPMENT AGREEMENT

Session 2:
Overview on Social Research on Fusion

Fusion energy economics

C.Bustreo, G.Zollino, G.Meneghini

CONSORZIO RFX
Ricerca Formazione Innovazione

UNIVERSITÀ DEGLI STUDI DI PADOVA

Satellite Meeting on the Socio-economic dimensions of Fusion Energy

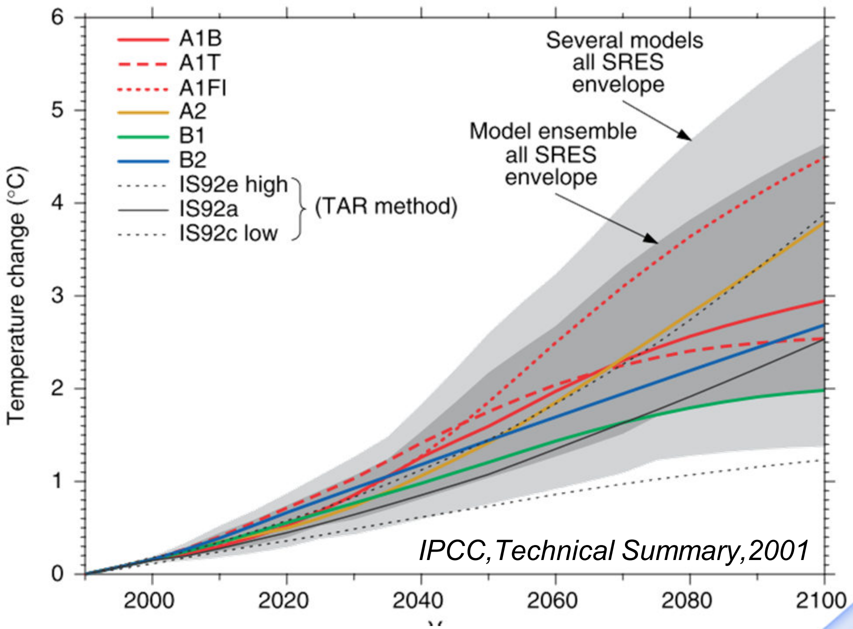
Barcelona, 19th September 2013

The context.

- Most of the current worldwide energy policies strongly support actions towards a decarbonised energy sector.
- From the **European «Energy Roadmap 2050»**:

«The EU is committed to reducing greenhouse gas emissions to 80–95 % below 1990 levels by 2050 in the context of necessary reductions by developed countries as a group.»

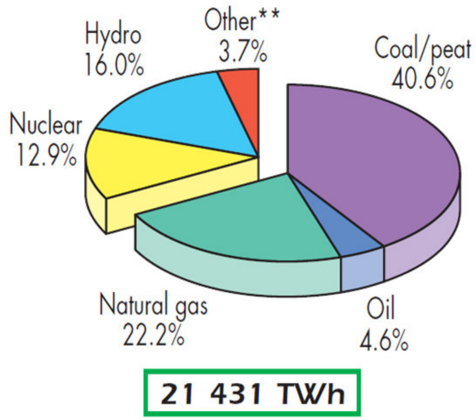
- The less will be the carbon dioxide emission in the athmosphere over the next decades, the lower will be the global temperature increase in the long term (year 2100).
- Anyway, a global temperature increase of 2 - 6°C as compared to 1990 levels is expected.



Who will be the actors of a fully decarbonized energy system?

- **Renewable energy.**
  - Intermittent energy source.
  - Thus RES need to be coupled with Storage Systems if they are supposed to provide the great part of the energy demand.
  - Large land use.
  - Upper bounds (technical and/or economical) on capacity to be installed.

World electricity generation by fuel in 2010
IEA, Key World Energy Statistic, 2012

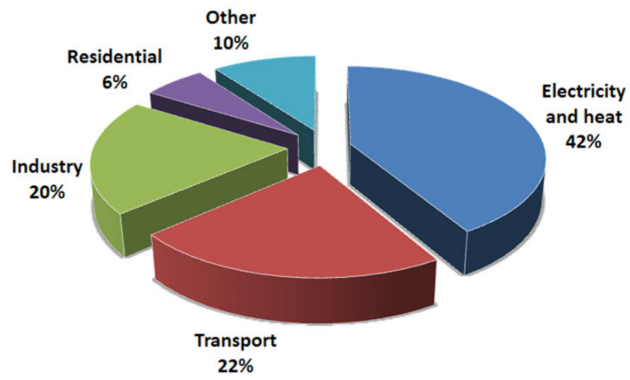


- **Fission power plants.**
  - Reduced social acceptability after Fukushima disaster,
  - even if the Gen III+ reactors ensure higher safety and security level.
  - The deployment of Gen IV reactors (~2030) would reduce the uranium consumption and long term waste thus helping fission sustainability.
  - The cost of electricity is low (~6 c€/kWh – median case @5% discount rate, $€_{2008}$, from Projected Cost of Generating Electricity 2010)

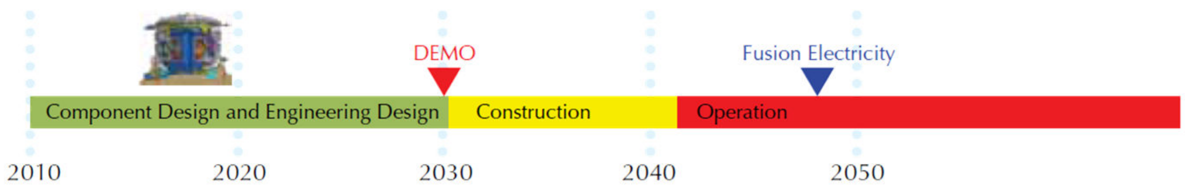
Who will be the actors of a fully decarbonized energy system?

- **Carbon Capture and Storage Systems.**
  - Would help reducing the emission of industry sector as well.
  - But most of the capture and storage technologies are still at demonstration phase
  - For ever coal+CCS Ppwill be more expensive than coal PP w/o CCS.

World CO2 emissions by sector in 2010
IEA,CO2 emissions from fuel combustiom, 2012



- **Fusion power plants.**
  - Available after 2050. For this reason it is not mentioned in IEA scenarios.
  - A number of technological and physical issues have still to be fixed.
  - The economics of fusion is under study as well.



Studies about fusion economics.

- Studies about the economics of fusion started in the late ‘70s.
- Currently they are carried out by U.S. (ARIES team), Europe (EFDA) and Japan (JAEA and some Universities).
- They all aim at estimating investment and running costs of a fusion power plant cost as well as its availability factor in order to estimate the **levelized cost of electricity**:

$$LCOE = p_{elc} = \frac{\sum_t (I_t + O\&M_t + F_t + C_t + D_t)(1-r)^{-t}}{\sum_t \left(E_t (1-r)^{-t}\right)}$$

Investment cost (I_t)
Operation and maintenance ($O\&M_t$)
Fuel (F_t)
Carbon Emission allowance (C_t)
Decommissioning (D_t)
Discount rate (r)
Electricity produced (E_t)

THE CHEAPER WILL BE THE ELECTRICITY FROM FUSION, THE GREATER DEPLOYMENT OF FUSION POWER PLANTS IS LIKELY TO OCCUR.

How do we get a global energy system outlook?

- In the framework of EFDA activities, a number of **scenarios**, i.e. a sort of pictures showing how the future global energy system might look like, are developed.

- This is done by the **TIMES model generator**.

- Besides a set of assumptions about the population and GDP growth, the features of both the energy demand sector and the energy supply sector, have to be declared.

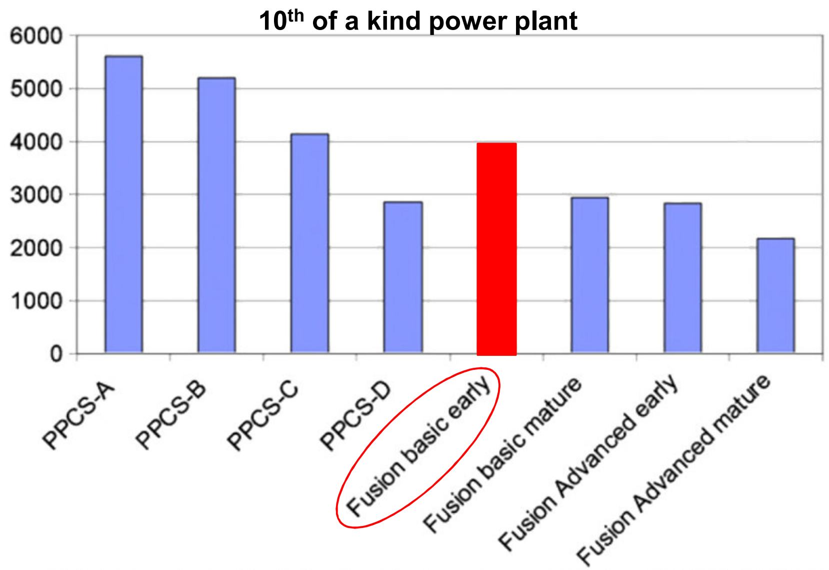
- In particular, each energy generating technology has to be fully described from a technical and economical point of view:
  - Overnight or Investment cost
  - Variable and Fixed O&M costs
  - Technological life
  - Efficiency
  - Availability factor.

Overnight or Investment cost, Technological life, Availability factor → have the highest impact on the LCOE

Fusion is a «capital intensive» technology.

- The **overnight cost** ($/kW) of fusion in the EFDA TIMES Model (**ETM**) comes from the European «Power Plant Conceptual Study».
- The ***assumed*** overnight cost of an early fusion technology in **2050,** looks to be in line with that of new fission power plants (Gen III+ and Gen IV).
- In ETM a **5 year lead time** is optimistically assumed for all nuclear technologies.

Fusion specific overnight cost ($2000/kW)*



*W.E. Han, D.J. Ward / Fusion Engineering and Design 84 (2009) 895–898

Overnight cost of technologies available in 2050 in ETM

	Overnight cost *$2000/kW*	Lead time *years*
Nuclear Fission	2400-3400	5
USC coal	1400	4
IGCC + CCS	2200	4
NGCC	700	2
Onshore wind	980	1
Offshore wind	1800	1
Solar PV	1800	1

NOTE: Costs are derived from a number of literature sources (for more details see EFDA reports, WP11)

Which expenditures are included in the Investment Cost?

- **Direct Costs:**
  - Structure and site facilities
  - reactor components (first wall, blanket, shield, divertor etc)
  - Power plant components (turbine plant equipment, electric plant equipment, energy storage system etc…)

- **Indirect costs**

  "expenses resulting from the support activities required to accomplish direct cost activities. They include Engineering Procurement Construction (EPC) costs, owner's costs (land, cooling infrastructure, administration and associated buildings, site works, switchyards, project management, licences, etc) and contingency cost, which is generally intended to compensate for uncertainty in cost estimates caused by performance uncertainties associated with the development status of a technology."

- **Interest During Construction**

  function of the lead time, of the cumulative expenditure pattern (usually S-shaped), of debt to equity ratio, of debt and equity rates, of taxes and inflation rate.

The uncertainties on fusion Investment Cost.

- **Financial issues.**

  Being fusion a capital intensive technology, it needs founding. The financial rules of the country where the power plant is built affects the Interest During Construction (IDC) amount and thus the Investment Cost which leads the LCOE.

- **Lead time.**

  The lead time is quite difficult to forecast especially in case of first-of-a-kind power plant (see as example the EPR construction in Europe). It also largely affects the IDC and thus the final Investment cost.

- **Cost of materials.**

  The cost escalation of raw materials already experienced with ITER could affect the Investment Cost estimation of a FPP.

The uncertainties on fusion investment cost.

- **Learning factor.**

  As much higher experience is acquired in producing specific components, as much lower is the production cost. For this reason the 10^{th} of a kind is likely to be cheaper than the first. But how much cheaper?

- **Replaceable components.**
  - How long will be the life of blanket and divertor?
  - How much time will be needed to replace them?

  These aspects largely affects the power plant availability factor.

THE LOWER IS THE POWER PLANT AVAILABILITY FACTOR (HOURS OF OPERATION/ HOURS IN A YEAR) , THE LOWER IS THE ANNUAL ELECTRICITY PRODUCTION AND THUS THE HIGHER IS THE COST OF ELECTRICITY.

Does the cost of fuel affect the cost of electricity?

- Similarly to fission, the cost of fuel has not a large impact on the cost of electricity:

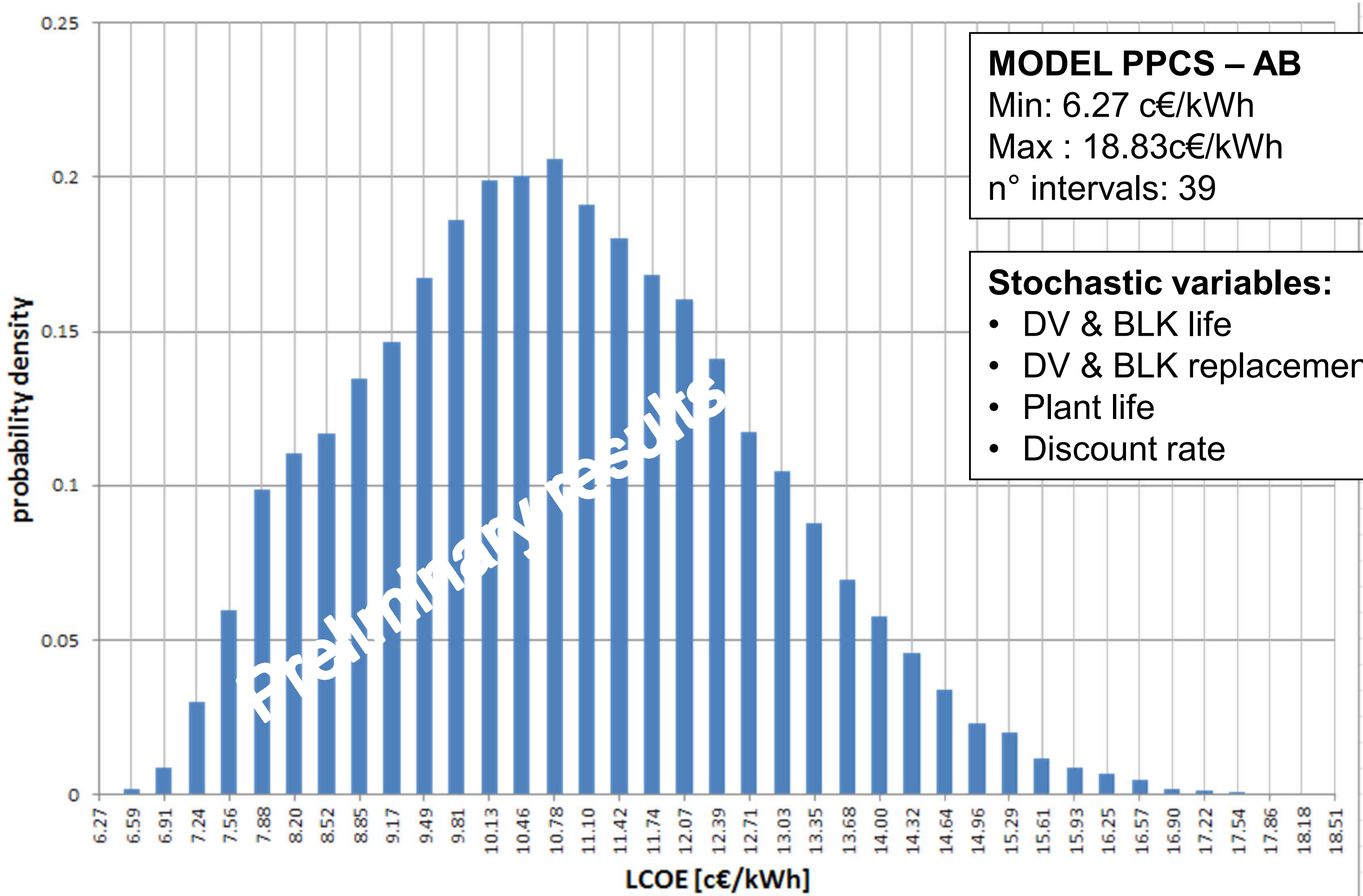
~ 70%	Cost of capital
~ 3%	O&M
~ 25%	BLK and DV replacement
~ 1%	Fuel
< 1%	Decommissioning

- A *simplified* nuclear fusion fuel cycle is modelled in ETM. Lithium is assumed to be the only fuel and its cost includes both the extraction and enrichment costs. The power plant is also assumed to be tritium self-sufficient (the initial supply coming from another running fusion power plant).

NOTE: On the contrary, the *complete* nuclear fuel cycle of fission power plants (production, reprocessing and spent fuel disposal) has been modelled in ETM being it the peculiarity of Gen IV reactors.

How to face such uncertainties?

- Preliminary results of a Monte Carlo analysis performed with **FRESCO** code in order to evaluate the impact of uncertainties on the **LCOE**:



MODEL PPCS – AB
Min: 6.27 c€/kWh
Max : 18.83c€/kWh
n° intervals: 39

Stochastic variables:
- DV & BLK life
- DV & BLK replacement time
- Plant life
- Discount rate

From MC analyses to ETM scenarios and vice-versa.

- The **Monte Carlo analyses** allows to estimate which is the most probable range of values of specific power plant economic parameters (investment costs, cost of electricity…)

- Through the **scenarios analysis**, generated by ETM, the conditions under which fusion is competitive in a future energy market can be deduced. These are specific combinations of environmental constraints and availability of new cheap and carbon-free electricity generating technologies.

Conclusions.

Merging these information we can assess:

If the power plant model under study might have chances to have a weight in a future energy market.

Or, from another point of view:

Which are the features of the power plant to be modified or the economic conditions to be ensured in order to make the fusion technology competitive.

Thank you!

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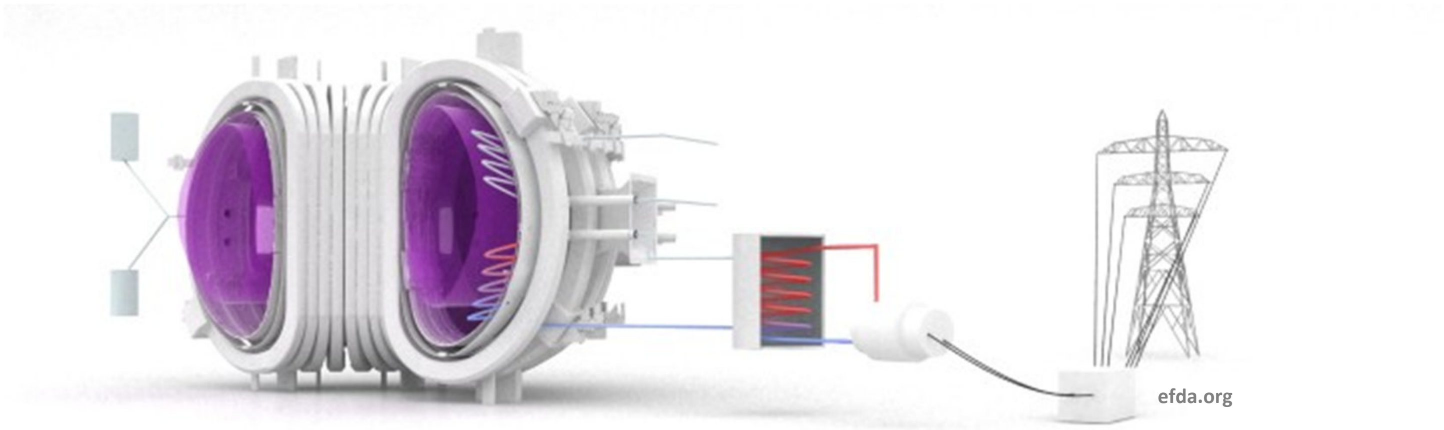

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Session 2:
Overview on Social Research on Fusion

Modelling future Energy Scenarios: EFDA TIMES

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CIEMAT
Centro de Investigaciones Energéticas MedioAmbientales y Tecnológicas

Satellite Meeting on the Socio-economic dimensions of Fusion Energy
Barcelona, 19th September 2013

GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Content

Some questions about the future global electricity system

What will be the Global Electricity System composition in 2100?

What will be the share of the electricity generated by fusion power plants in 2100?

Would fusion be competitive in the future electricity market?

At what extent will fusion contribute to meet the global environmental targets?

Energy models and scenarios

Energy models are computer tools to analyse the behaviour of the energy system at a medium and long term under different environmental and energy policies

Scenarios are not predictions either forecasts. Scenarios explore the future and discuss how to shape it with a rational discourse [1]

[1] GianCarlo Tosato. Insight in global long term energy scenarios, lessons learnt. IPP Report No. 16/13. March 2007

EFDA Times Model (ETM)

The EFDA Times model (ETM) has been built in the framework of the European Fusion Development Agreement, within the Socio-Economic Research on Fusion project (SERF)

ETM uses the TIMES model generator developed by IEA-ETSAP (IEA Energy Technology Systems Analysis Programme Implementing Agreement)

First version was produced in 2004. Last version in 2012

Model description

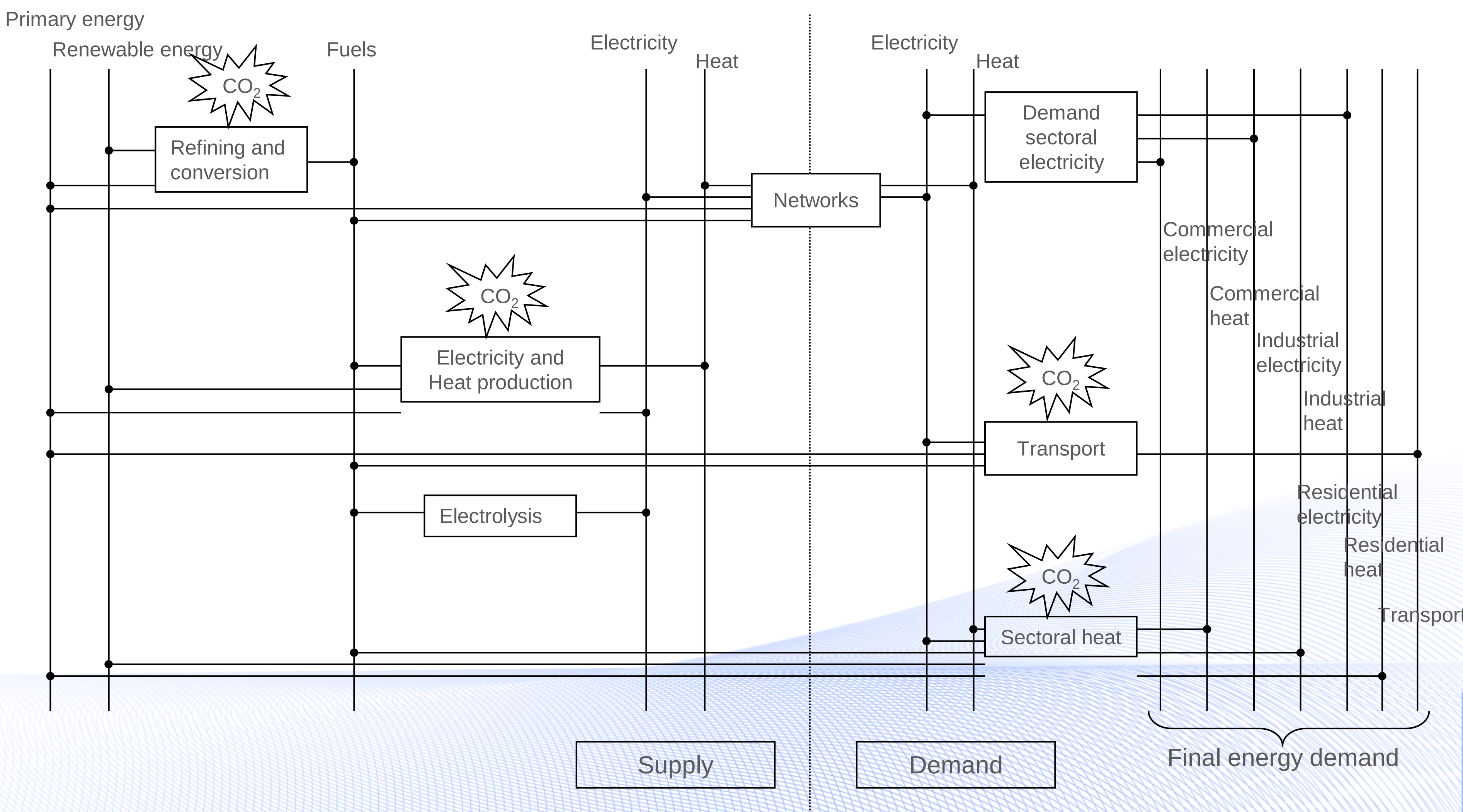
The EFDA Times Model is a

✓ Multi-regional, global, and long-term energy model of economic equilibrium, covering the entire energy system from mining to final consumption

✓ Optimization model which aims at providing the optimum energy system composition in terms of social wealth and sustainability at the minimum cost

✓Bottom-up, technology rich model with thousand of technologies well defined by technical, economic and environmental data

Model structure



The Reference Energy System

Main ETM objective

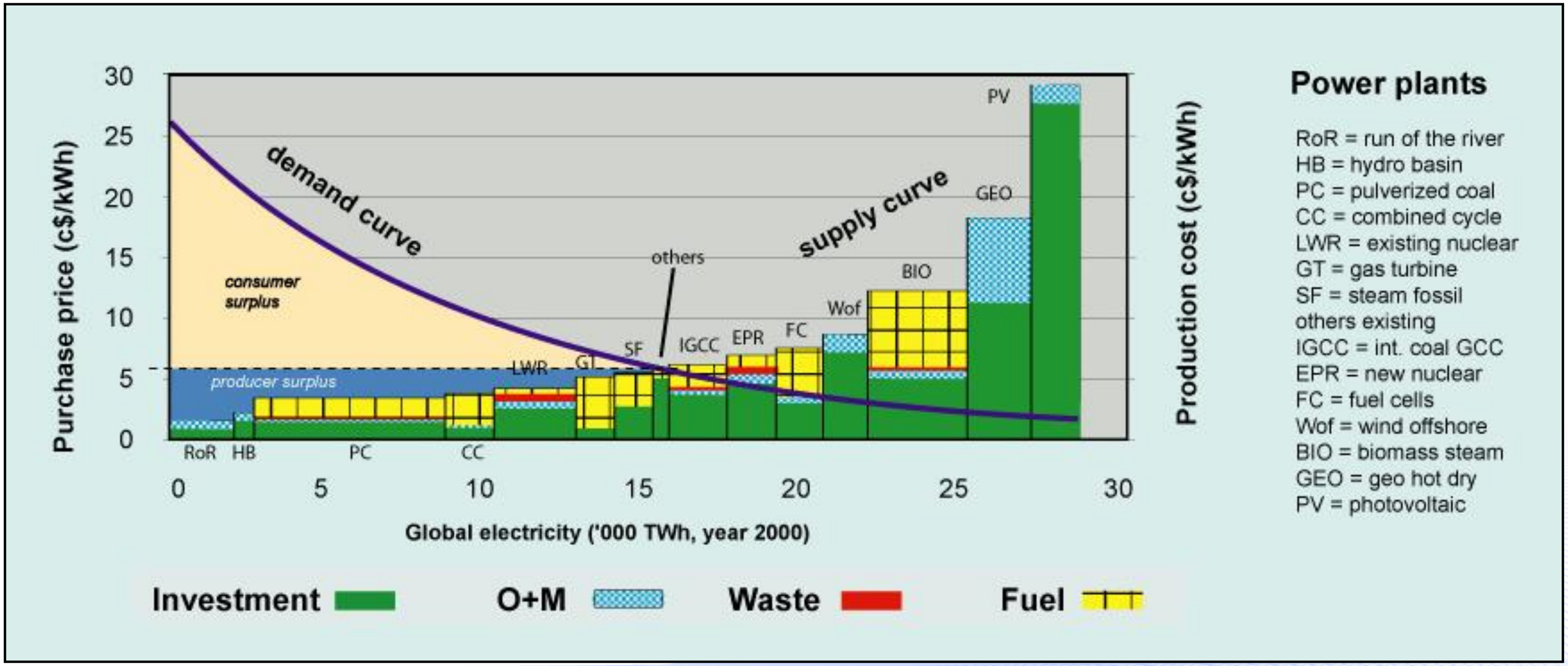
To develop consistent long-term energy scenarios containing fusion as an energy option, and showing the potential benefits of fusion power as an emission free energy source

What makes ETM singular?

Unlike other global energy models, ETM describes the whole fusion sector from Lithium extraction to electricity production by fusion plants

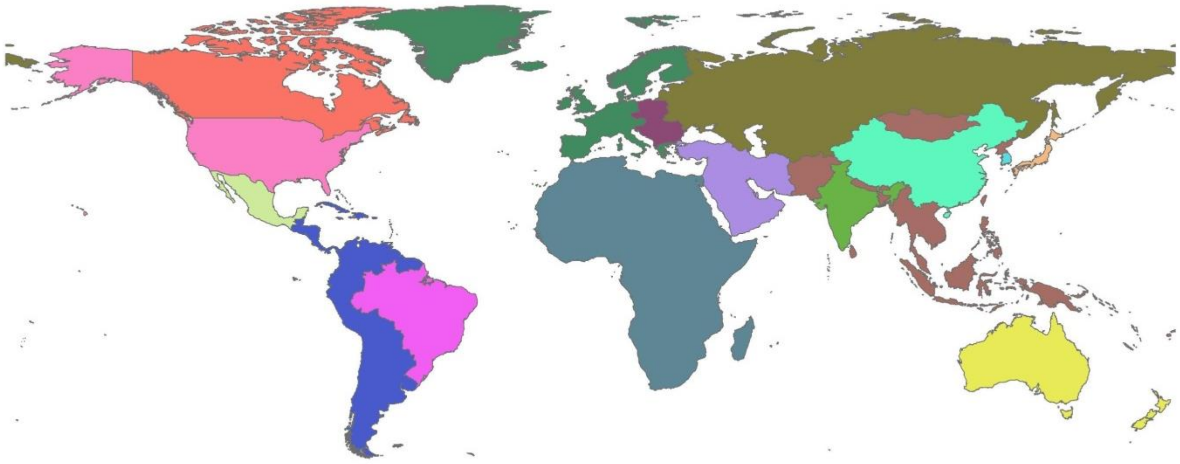
Advanced nuclear fission fuel cycle also described in detail into the model

Market equilibrium



Source: ETSAP (http://www.etsap.org/Images/MT_Results.jpg)

Main characteristics



- 17 world regions: Africa, Australia-New Zealand, Brazil, Central Asia and Caucasus, Canada, China, Europe, India, Japan, Middle East, Mexico, Other Developing Asia, Other Eastern Europe, Other Latin America, Russia, South Korea, and United States
- Time horizon: 2100
- Six time slices: three seasons (winter, summer and intermediate), and day/night
- Demand sectors: residential, commercial, agriculture, industry, and transportation
- Supply sectors: electricity and heat production, and upstream
- Demand scenarios: energy demand driver projections from the general equilibrium models GEM-E3 and Gtap
- Trade: inter-regional exchange process (trade of commodities) among the different regions

Fusion technologies in the model

Fusion power plants economic data [2] [3]

	Start	Life	AF	INV (€/kW)	FIXOM (€/kW)	VAROM (€/MWh)
Basic plant	2050	40	85%	3940 (10th) 2950 (100th)	65.8	2.16 (2050) 1.64 (2060)
Advanced plant	2070	40	85%	2820 (10th) 2170 (100th)	65.3	2.14 (2070) 1.64 (2080)

Other technologies

- ✓ Current and future Nuclear Fission Fuel Cycle technologies including spent fuel reprocessing
- ✓ Concentrating Solar Power with energy storage
- ✓ New biofuels and electric vehicles
- ✓ …..

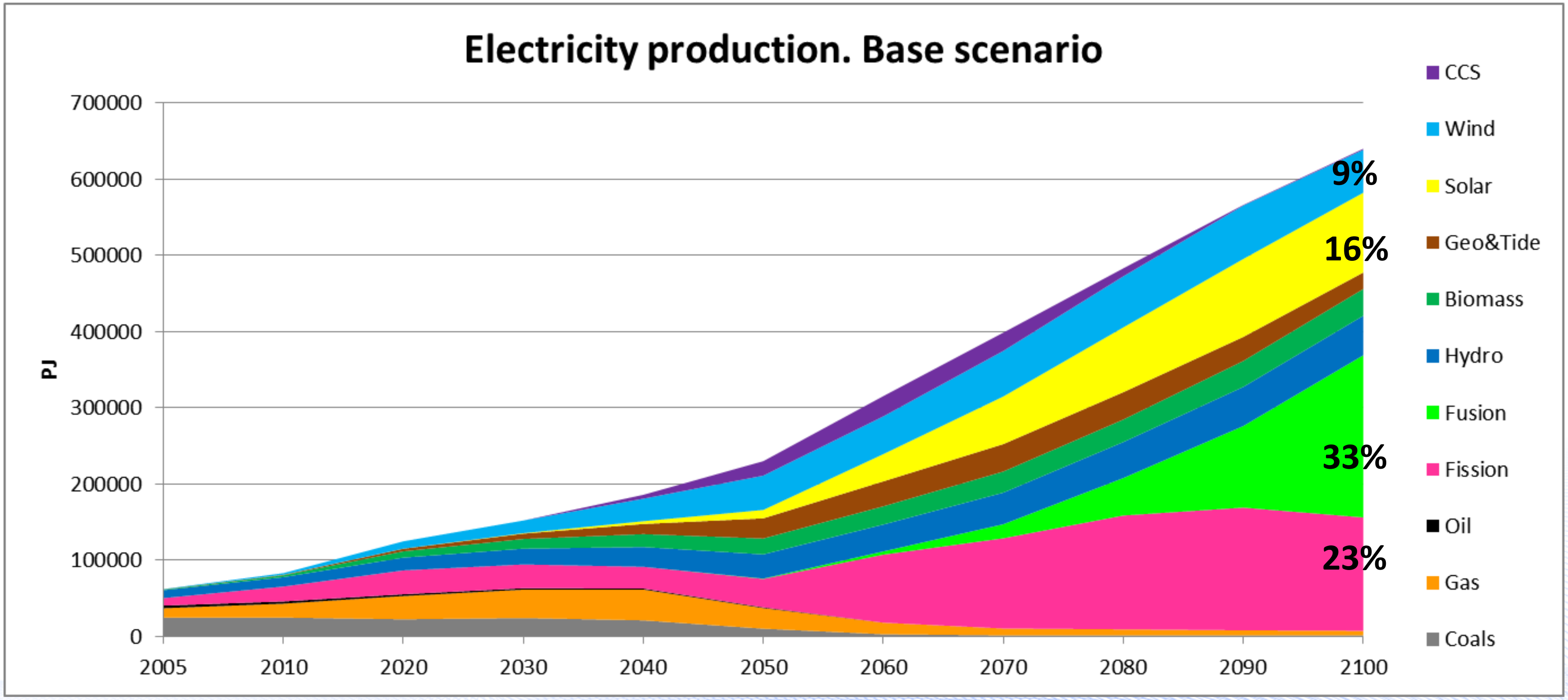
[2] Han W.S. and Ward D. Revised assessments of the economics of fusion power. *Fusion Engineering and Design* 84 (2009) 895-898
[3] Maisonnier D. *et al.* The European power plant conceptual study. *Fusion Engineering and Design* 75-79 (2005) 1173-1179

SCENARIOS

	ENVIRONMENTAL CONSTRAINS	TECHNOLOGY AVAILABILITY		DEMANDS	COSTS			
	550 ppm	NO FUSION	NO CCS	HIGH	FUSION VAROM	FUSION INVCOSTS	SOLAR CSP COSTS	WIND COSTS
01-BASE	√			√				
02-NO FUSION	√	√		√				
03-NO CCS	√		√	√				
04-05-FUSION VAROM ±20%	√			√	√			
06-FUSION INVCOSTS +50%	√			√		√		
07-10-LOW SOLAR CSP COSTS (-15%, -25%, -35%, -50%)	√			√			√	
11-14-LOW WIND COSTS (-15%, -25%, -35%, -50%)	√			√				√

RESULTS

Base scenario results



33% of fusion electricity in 2100. 42% of renewables. 23% of fission . 1% gas.
Coal phases out around 2060 and gas technologies reduce their share
CCS techs play a role in the mid of the century

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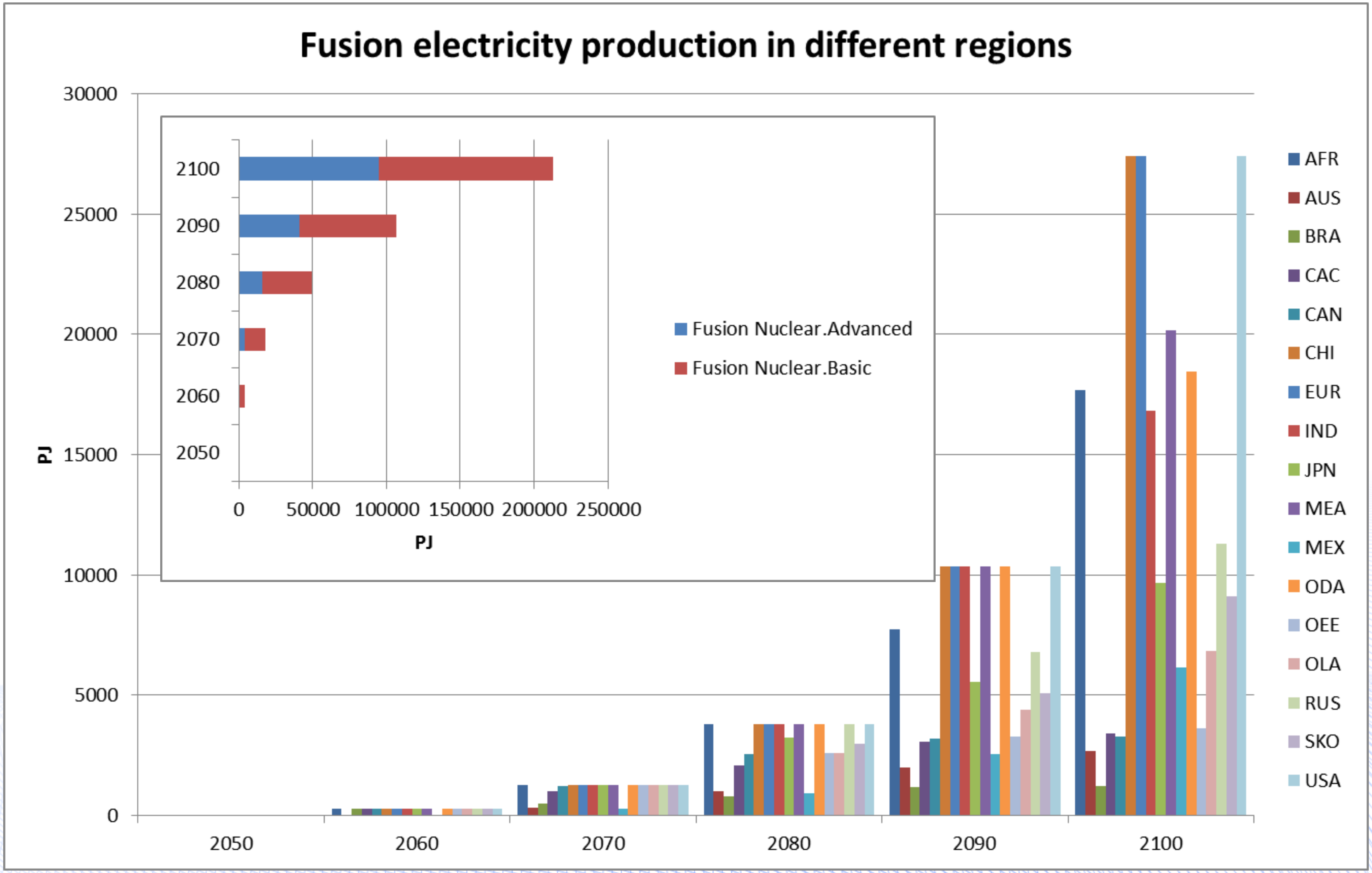
Fusion deployment in different regions of the model



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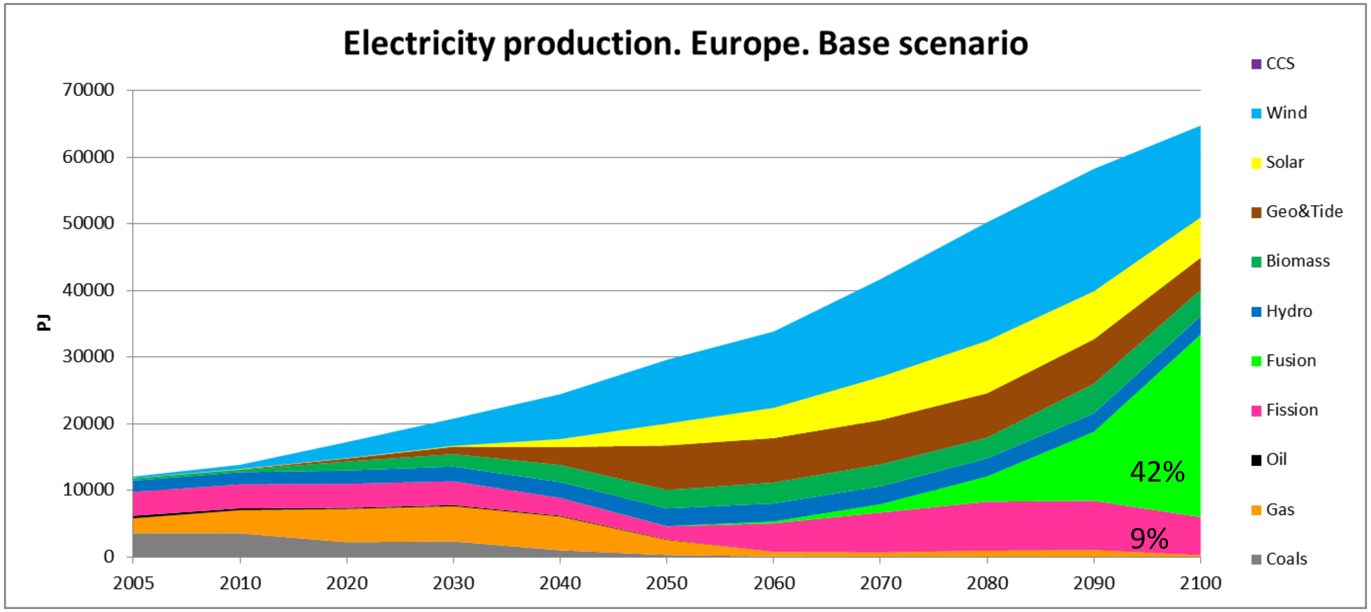
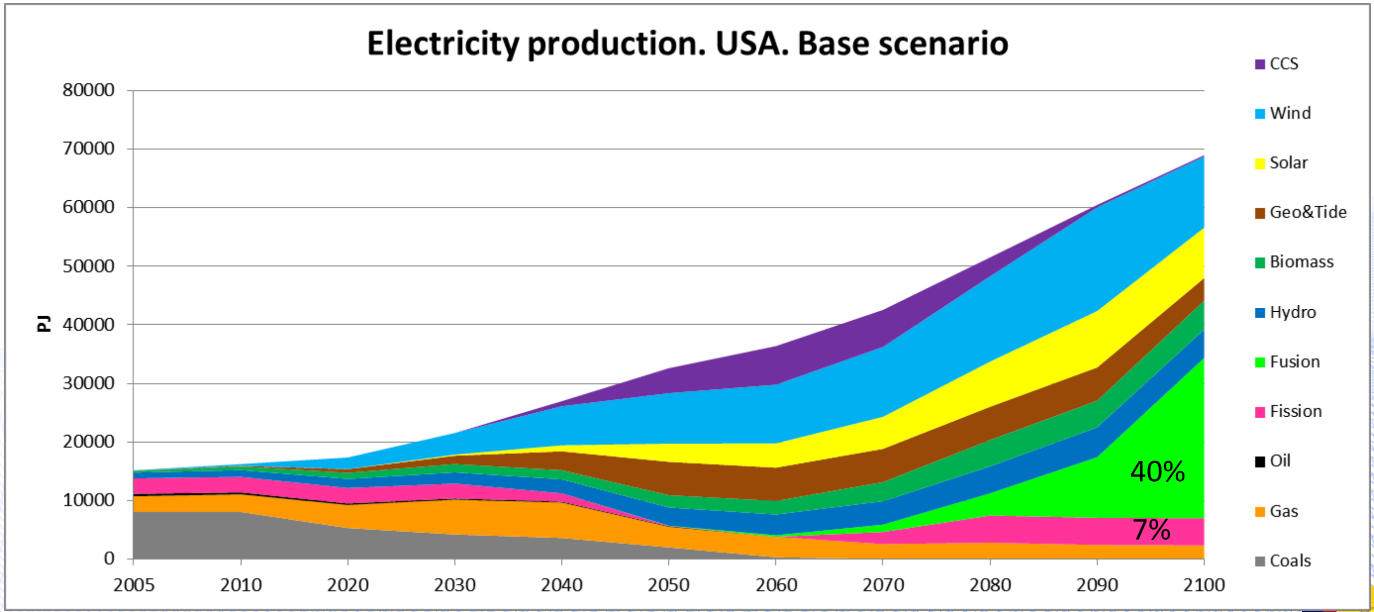
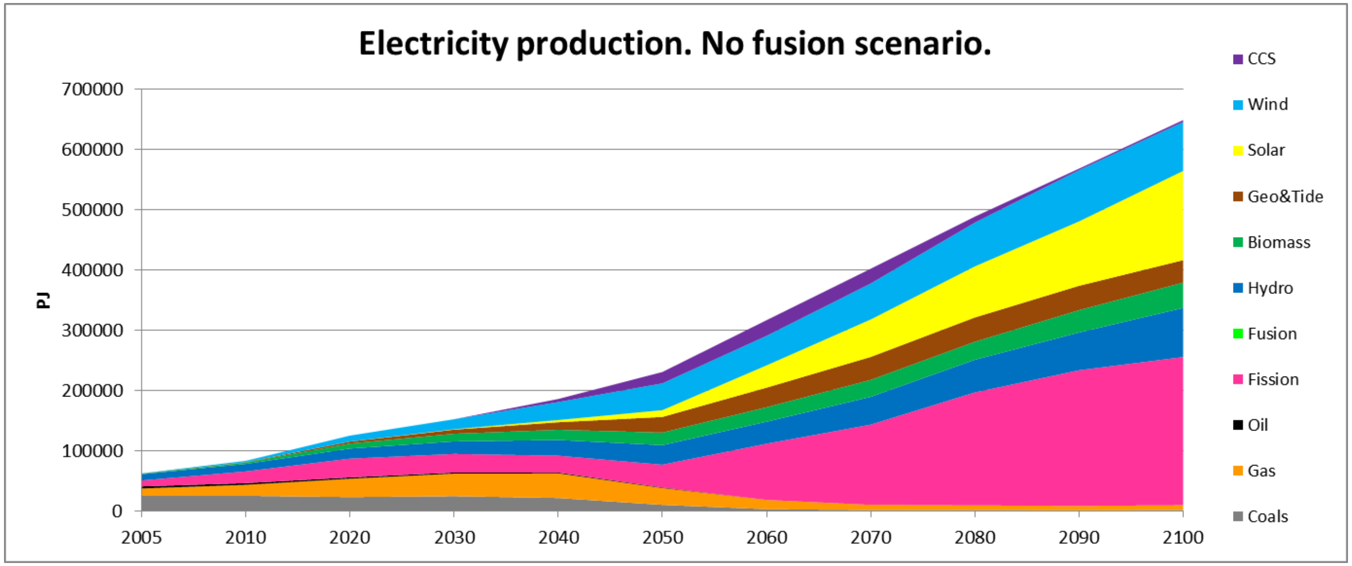


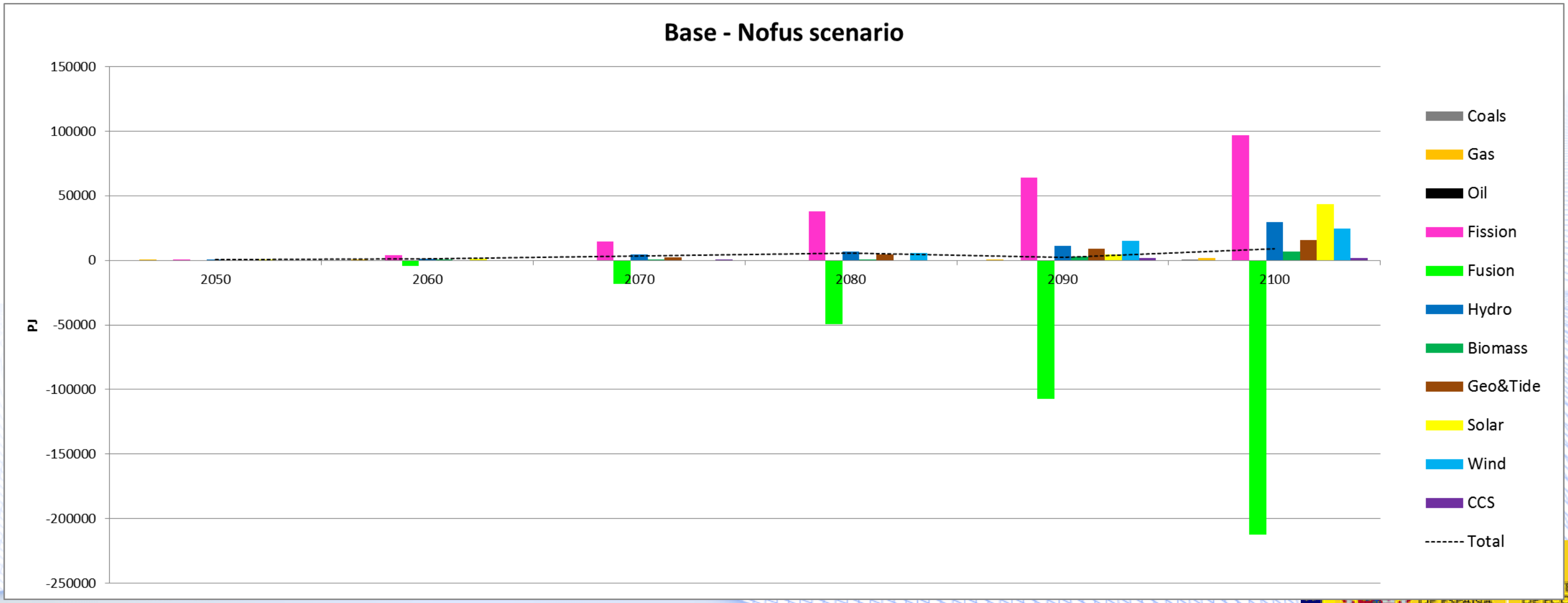


Europe and USA, the regions with highest fusion electricity production

Sensitivity analysis on technology availability

If fusion is not available, fission technologies take most of its production along with other renewable technologies





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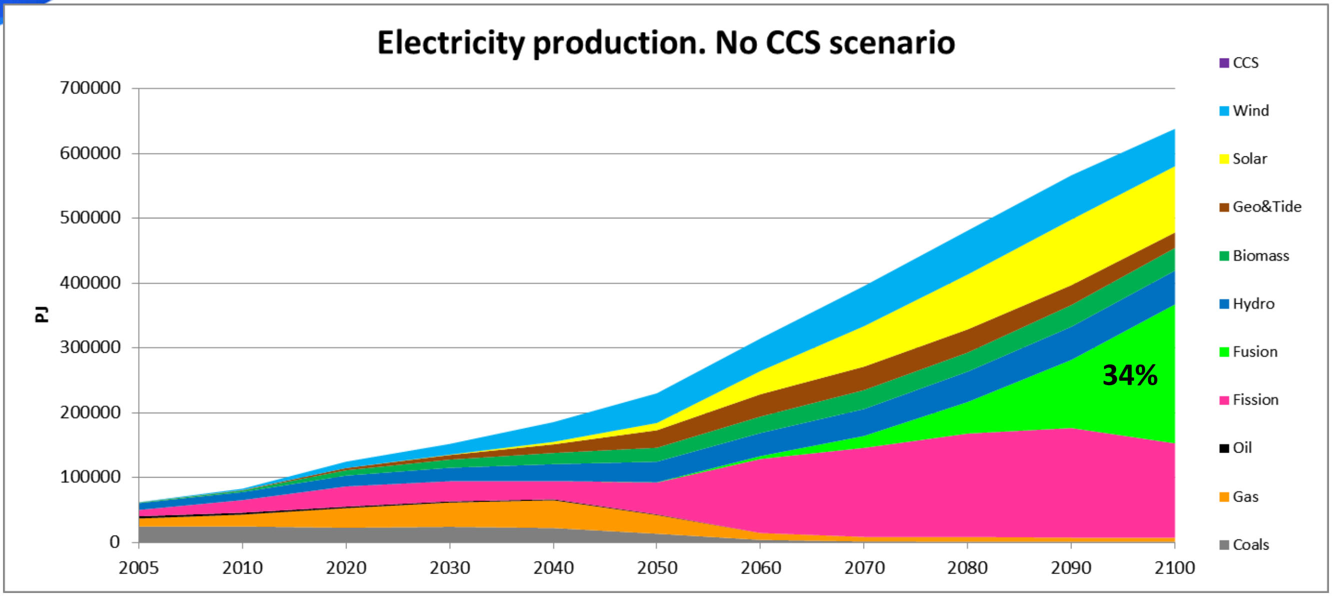
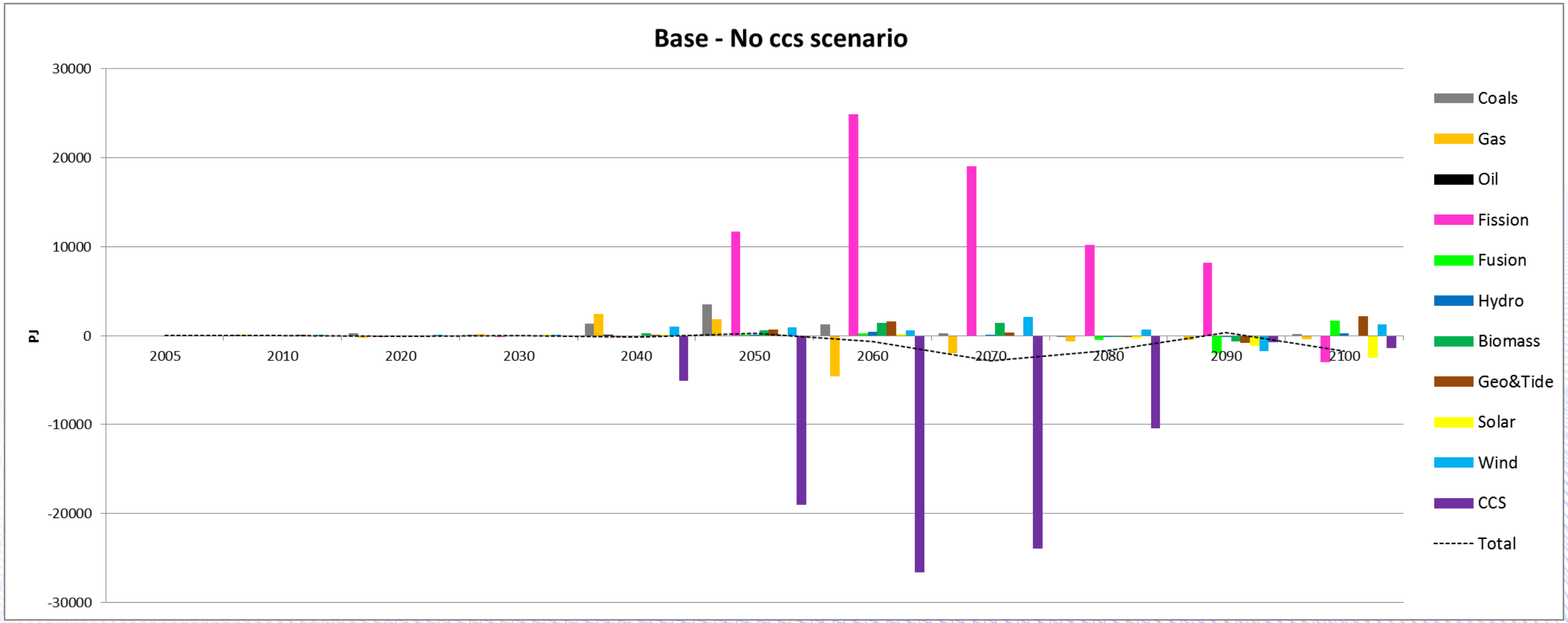
CCS electricity production share is taken up by fission technologies and fusion penetration is not greatly affected





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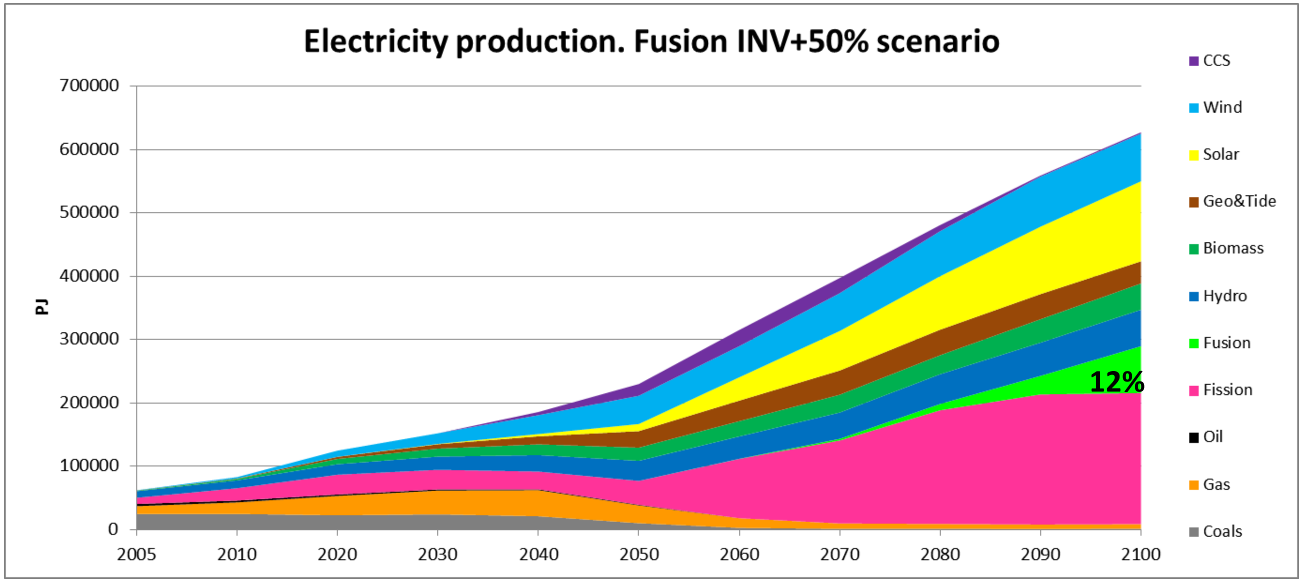
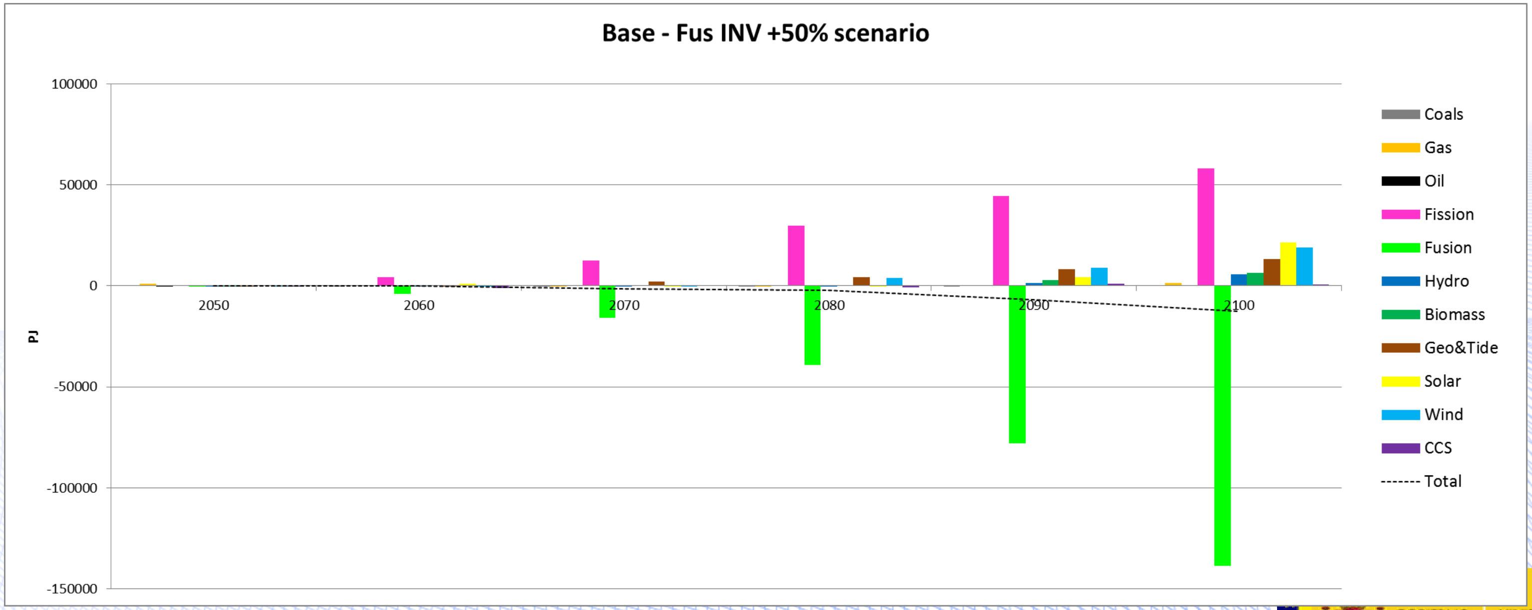
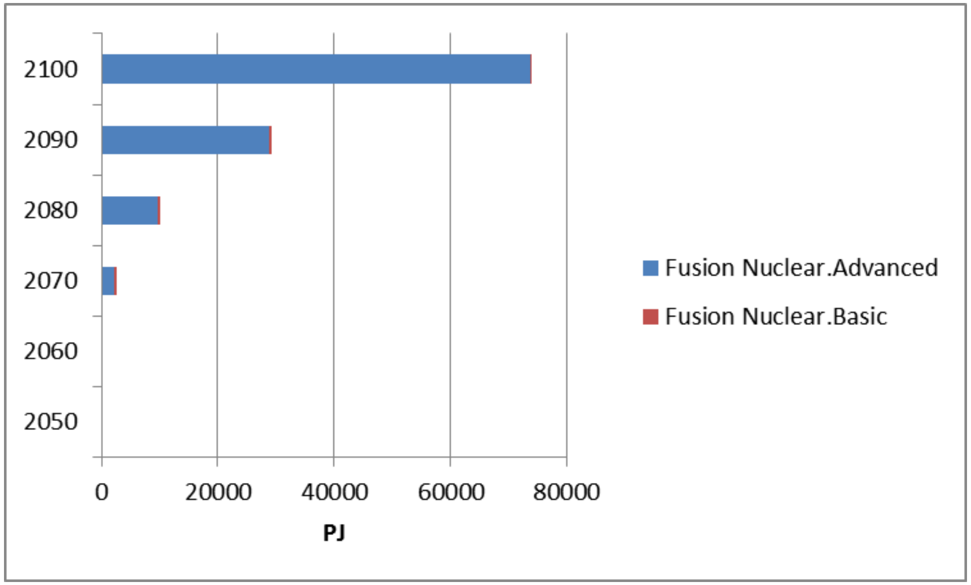
Fusion costs sensitivity analysis

Fusion share in 2100 goes down to a 12%, being substituted by fission and in a lower degree by renewables

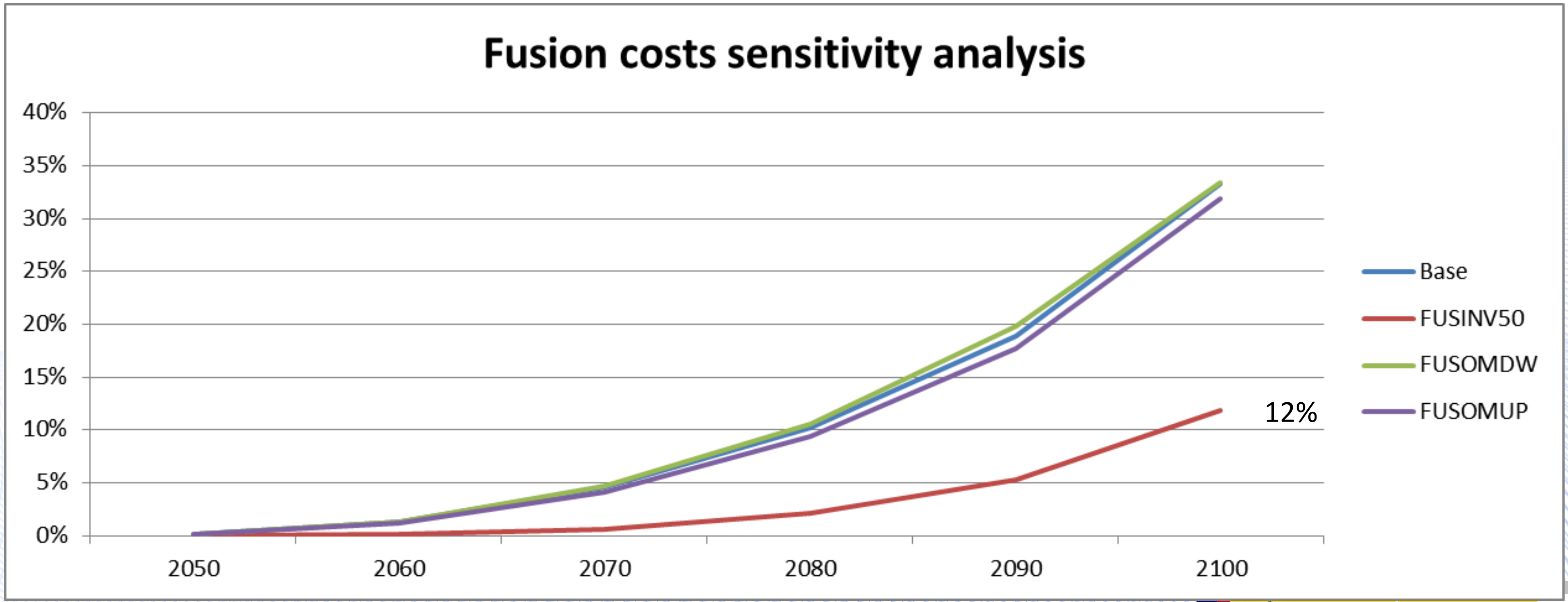






Advanced reactors are preferred and the deployment of the technology is delayed until these advanced reactors are available in the market.

Differences in the O&M costs are not expected to have a big impact on the market penetration of fusion technologies



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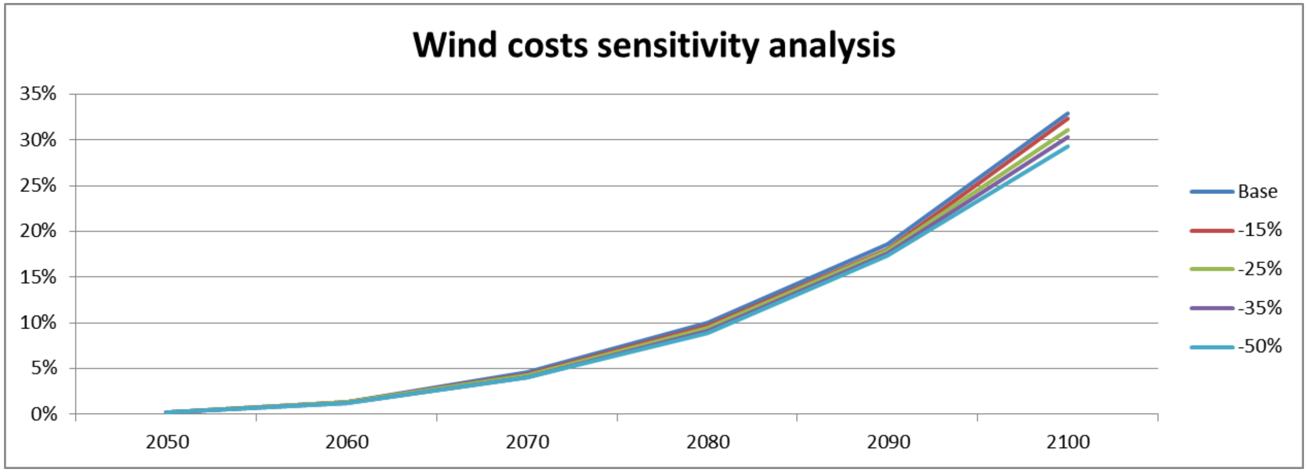
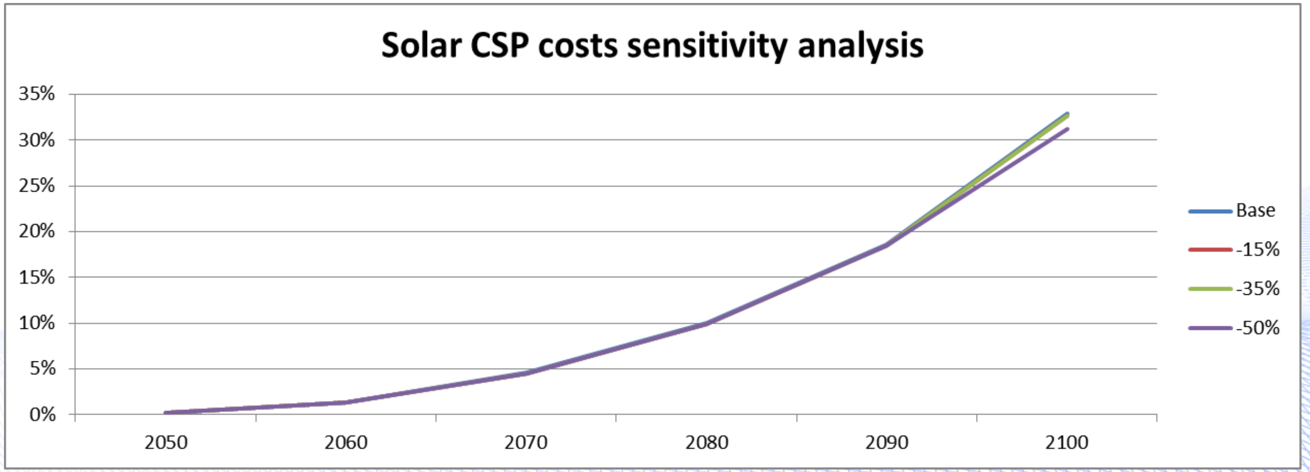
Renewable energies costs sensitivity analysis





Fusion share would not affected by the availability of cheaper renewable technologies in the market.

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CONCLUSIONS

- The costs of fusion power plants are **competitive enough** to allow the deployment of the technology once it is available in the market reaching a significant share (33%) in 2100 in the context of an almost fully decarbonized electricity system.
- According to the model results, fusion technology would be deployed in all the regions and both the basic and the advanced technologies would be selected by the model.
- A sharp increase in the **investment costs** (+50%) that could be originated by a great escalation of the costs of materials has a **big impact on the penetration of the technology**. The deployment of the technology is delayed and the share in the market only reaches 12% in 2100. The advanced technology is preferred then.
- A 20% variation of **O&M costs** does not produce a big change in the market penetration of the technology . We can conclude then that the life of replaceable components (blanket and divertor) is **not expected to have a big impact** in the deployment of the technology.
- The availability of **CCS technologies** in the electricity market does **not influence** the market penetration of fusion power plants
- The availability of **cheaper renewable technologies** does **not have an impact** on fusion penetration

Thank you!

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ANNEXES

	Model A	Model B	Model C	Model D
Parameter (plasma physics)				
Unit Size (GW_e)	1.55	1.33	1.45	1.53
Fusion Power (GW)	5.00	3.60	3.41	2.53
Aspect Ratio	3.0	3.0	3.0	3.0
Elongation (95% flux)	1.7	1.7	1.9	1.9
Triangularity (95% flux)	0.25	0.25	0.47	0.47
Major Radius (m)	9.55	8.6	7.5	6.1
TF on axis (T)	7.0	6.9	6.0	5.6
Plasma Current (MA)	30.5	28.0	20.1	14.1
β_N(thermal, total)	2.8, 3.5	2.7, 3.4	3.4, 4.0	3.7, 4.5
Bootstrap Fraction	0.45	0.43	0.63	0.76
P_{add} (MW)	246	270	112	71
n/n_G	1.2	1.2	1.5	1.5
Parameter (engineering)				
Average neutron wall load	2.2	2.0	2.2	2.4
Divertor Peak load (MWm^{-2})	15	10	10	5
H&CD Efficiency	0.6	0.6	0.7	0.7
Plant Efficiency*	0.31	0.37	0.42	0.6
Coolant blanket	Water	Helium	LiPb/He	LiPb
T_{in}/T_{out} (°C)	285/325	300/500	480/700 300/480	700/1100
Coolant divertor	Water	Helium	Helium	LiPb
T_{in}/T_{out} (°C)	140/167	540/720	540/720	600/990
Power conversion	Rankine	Rankine	Brayton	Brayton

* the plant efficiency is the ratio between the unit size and the fusion power

Table 1: Main parameters of the PPCS models.

[2] Maisonnier D. *et al.* The European power plant conceptual study. *Fusion Engineering and Design* 75-79 (2005) 1173-1179