The State and Prospects of Fusion Energy workshop

(CERT thematic discussion)

International Energy Agency

Bird's eye view on world-wide strategies towards Fusion Power Plants

David Maisonnier — Chair of the I.E.A. Fusion Power Co-ordinating Committee (FCPP)

david.maisonnier@izi-fusion.eu

26 February 2025 — IEA HQ, Paris (FR)

Introduction

For the purpose of this talk, a strategy defines the goal(s) to be achieved and outlines the actions to achieve them. A roadmap is a more detailed, resource-loaded plan to achieve the strategic goals.

CN, **EU**, **JA**, **UK** and **US** have the 5 main fusion development programs in the world, and they all have a strategy and/or a roadmap to develop fusion energy. Summarising each of these programmes with 2 slides is rather challenging…

There is an increased political support worldwide for fusion in individual countries, but also in international fora, in particular the IAEA Fusion Energy Group and the G7 Working Group on fusion, both of which had their first meeting at the end of 2024.

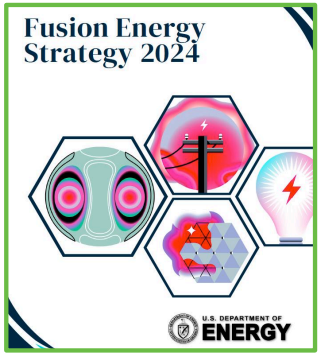
This increased support, together with the proliferation of fusion startups and the massive injection of private capitals the last few years, translate an epochal change in the development of fusion energy.

Could or should the IEA strengthen its role in the development of fusion energy?

US (1 of 2)

17/03/2022, White House summit: Decadal Vision for Commercial Fusion Energy.

6/06/2024, White House summit: DOE Fusion Energy Strategy and its vision for its Fusion Energy Science Program ('Building Bridges'), kick-start PPP with 8 companies to advance designs and research and development for private-sector-led fusion pilot plants (46MUSD for the first 18 months of a 5-year program).



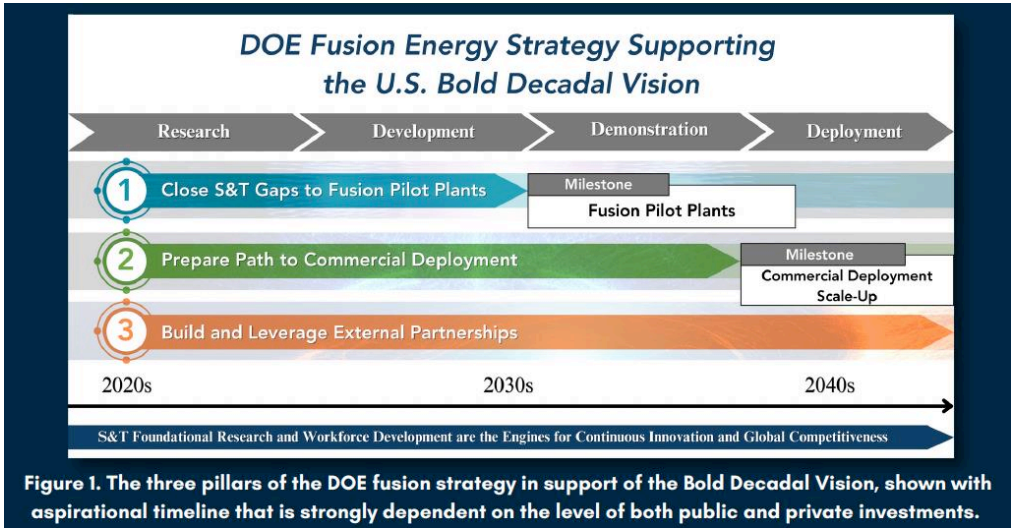
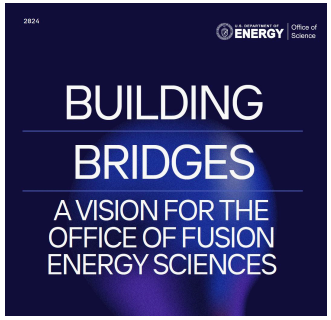


Figure 1. The three pillars of the DOE fusion strategy in support of the Bold Decadal Vision, shown with aspirational timeline that is strongly dependent on the level of both public and private investments.



Pillar 1 is supported primarily by "building bridges":

(1) develop a roadmap (to be released in 2025)

(2) FIRE (funding of fusion S&T grants, launched)

(3) PP Consortium Framework, e.g. ARPA-E

Thanks to Dr Scott C. Hsu (DOE)

US – Takeaways (2 of 2)

Key assumption is that first fusion pilot plant will be built by private sector.

DOE needs to refocus R&D on low TRL technologies and let industry take responsibility for higher TRL technologies. Plasma physics still important, but need to shift emphasis from physics to engineering.

Cost of first pilot plant likely to be too high to be financed only by private sector. Need to develop adequate concepts to provide public subsidies.

Fusion in the US is following the same path as aerospace: yesterday NASA; today space -X, Blue Origin, and ULA (United Launch Alliance).

The strategy is clear and relies strongly on the private sector – typical US. It has worked for space, why not for fusion (provided the public financial support is adequate)?

https://www.whitehouse.gov/ostp/news-updates/2022/03/15/fact-sheet-developing-a-bold-vision-for-commercial-fusion-energy/

https://www.energy.gov/sites/default/files/2024-06/fusion-energy-strategy-2024.pdf

https://www.energy.gov/sites/default/files/2024-06/fes-building-bridges-vision.pdf

Industry

I consulted Fusion Industry Associates (FIA) to ask about their "strategic views". Other industrial associations (EFA, EUBFA, J-Council) are younger and with limited membership, I did not consult them.

FIA members are mostly from the US, and FIA's views are well aligned with the DOE strategy:

- Support public research (1) to close open S&T gaps common across industry – in particular fuel cycle and materials, (2) for building the test stands necessary for a research program.
- Ask for a risk-appropriate regulatory regime fully and permanently separated from nuclear fission. Ideally, it will also be globally harmonized.
- The public will have to be supportive of the mass deployment of fusion ☞ needs for a significant education and outreach program that informs about fusion.
- Advocate public support to private industry to build the (first) fusion pilot plants.

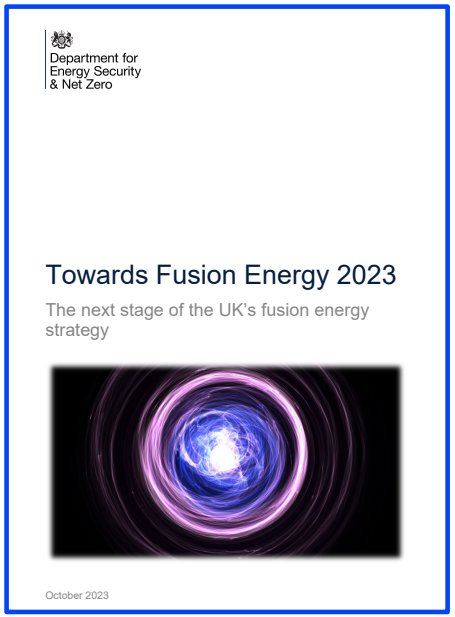
Takeaway

- FIA views well aligned with US-DOE strategy.
- The assumption that the first FPP will be built by private industry is probably not shared by all industries outside the US (in particular in the EU).

Thanks to Andrew Holland (CEO of FIA)

UK (1 of 2)

UK fusion development strategy issued in Oct. 2023 (update of 2021 strategy).



Objectives for UK fusion

For the UK to demonstrate the commercial viability of fusion by building a prototype fusion power plant in the UK that delivers net energy.

For the UK to build a world-leading fusion industry that supports different fusion technologies and is capable of exporting fusion technology in subsequent decades.

The three pillars of the UK strategy:

Objectives for fusion international leadership

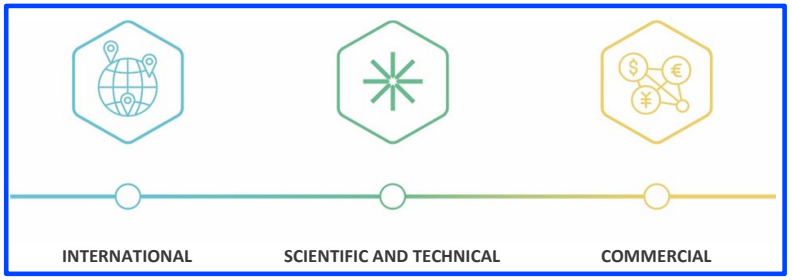
Use INCO to accelerate commercialisation of fusion energy.
Reduce cost and risk of UK programmes while protecting UK IP and competitive advantage.
Lead the development of int. fusion standards and regulation.

Objectives for fusion scientific and technical leadership

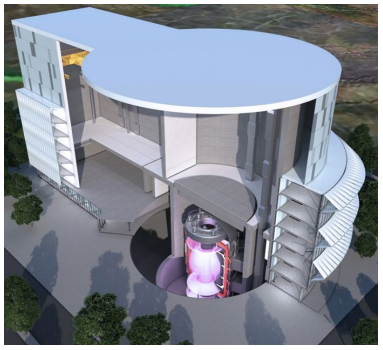
Maintain global leadership in fusion science, technologies and facilities.
Attract, grow and retain leading fusion talent, including supporting engineering disciplines.
STEP – Spherical Tokamak for Energy Production (to be build by 2040, West Burton site selected), UK Industrial Fusion Solutions Ltd (wholly owned subsidiary of UKAEA, https://step.ukaea.uk).
Decommissioning of JET; other UK fusion facilities (MAST U, RACE, MRF, CLF…).

Objectives for fusion commercial leadership

Create a vibrant fusion technology cluster(s) in the UK.
Attract inward investment into fusion, develop supply chain and skills base.
UK firms to compete successfully in a future global fusion market.



UK – Takeaways (2 of 2)



STEP and the West Burton site
(before develomment for STEP)

Following BREXIT and its decision not to be associated to Euratom, the UK has developed and implements its own, clear fusion development strategy.

In addition to the demonstration of the commercial viability of fusion, the strategy aims to build a UK world-leading fusion industry.

Selecting a concept (STEP) and a site for its future fusion pilot plant are very concrete and serious actions.

Following the change of government in July 2024, support for fusion development has been confirmed.

Never underestimate the UK!

https://www.gov.uk/government/publications/towards-fusion-energy-the-uk-fusion-strategy/5b7f10b9-1b7e-4b88-8f1b-61bae50f625a

Philosophical Transactions A, titled: “The Spherical Tokamak for Energy Production (STEP): Pioneering Fusion Powerplant Design

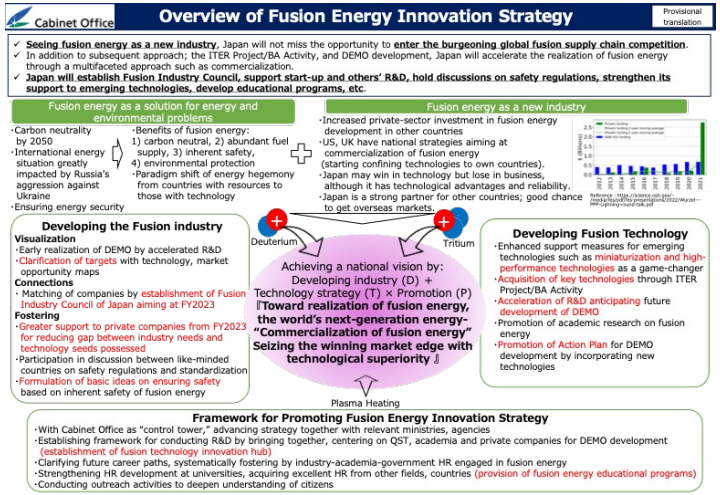
Japan (1 of 2)

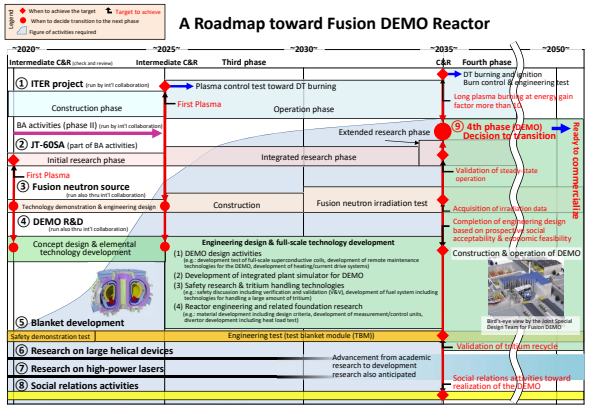
The Integrated Innovation Strategy Promotion Council issued on 14/04/2023 the Japanese "Fusion Energy Innovation Strategy".

Strategy defined/approved by the Cabinet Office (office of the prime minister).

Several references to recent developments in the US, UK, and CN, also to ITER and the EU-JP BA Agreement).

https://www8.cao.go.jp/cstp/fusion/230426_strategy.pdf





The Japanese fusion roadmap, issued in 2018, is being updated. Main issue: effects of ITER re-baselining.

New/revised roadmap expected in 2025.

FAST (Fusion by Advanced Superconducting Tokamak)

Private initiative, unlikely to be an official element of the new J-roadmap. On the other hand, the private sector is anticipated to have an important contribution.

Thanks to Dr Tomohiro Morisaki (NIFS, FPCC vice-chair)

Japan (2 of 2)

INCO remains important.

Collaboration with China: complicated. IFS (Institute of Fusion Science, Southwest Jiaotong University, China) and NIFS (National Institute of Fusion Science, Japan) signed an agreement in 2017 to design and build CFQS (Chinese First Quasi-axisymmetry Stellarator) in Chengdu.

(https://iopscience.iop.org/article/10.1088/1741-4326/ac369a).

Takeaways

Strong political support for fusion, new strategy driven by Cabinet Office.

Japanese views well aligned with EU ones (all to be confirmed in new J-roadmap):

- tokamak remains main line of fusion power plant development;
- importance of ITER confirmed, but need to assess effects of rebaselining;
- INCO remains important/essential.

Work on DEMO not as advanced as in the EU (very limited JP contribution to BA IFERC project).

Contribution of private sector expected to increase, driven primarily by Kyoto Fusioneering. Contribution of Supply Chain industry unclear, but should not be underestimated.

China (1 of 2)

Strong political support for fusion in China (opinion by Comunist Party of China and by State Council in support of fusion development), but there is no official CN fusion strategy or roadmap and there seems to be no plan to formalise one soon.

Main focus of fusion research in China is on MCF, in particular the tokamak option. Main devices in operation are HL-2M/HL-3 and EAST, supported by smaller devices located mostly in Universities and by a strong domestic R&D programme and INCO.

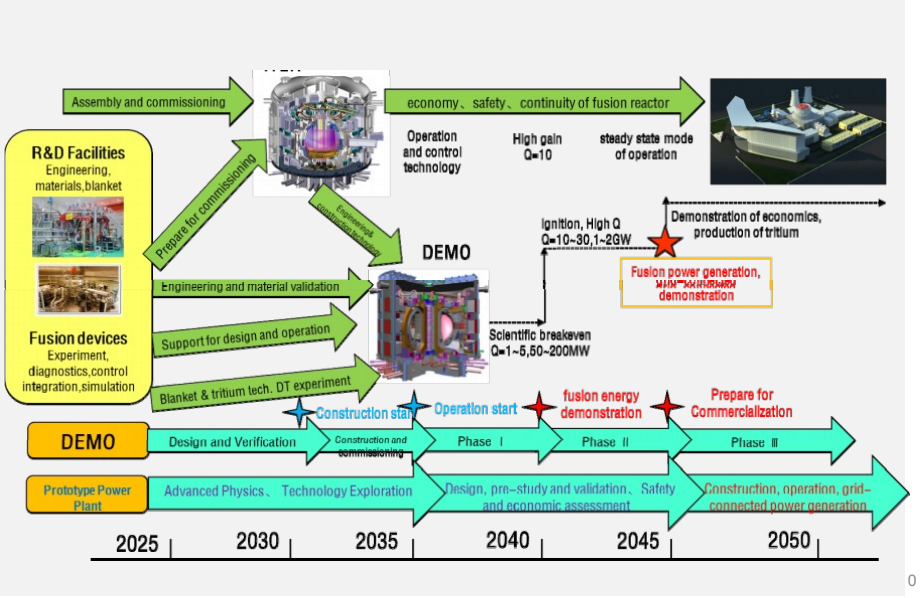
China participates in ITER and in the IEA fusion Technology Cooperation Programs (TCPs).

MOST (Ministry of Science and Technology, host of ITER CN-DA) provided the attached draft, with no mention of ASIPP (Chinese Academy of Science, Institute of Plasma Physics) activities!

ASIPP has a clear roadmap: EAST-BEST-CFETR.

A fusion private sector is also emerging, the main company being ENN, focusing on the proton-boron reaction.

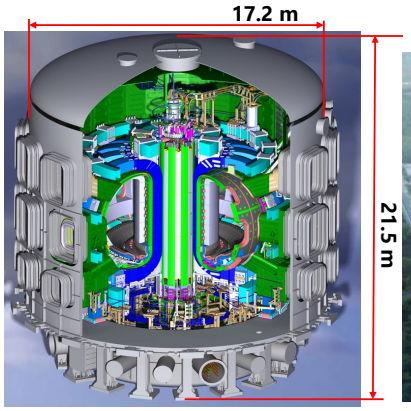
Thanks to Dr Shen Xinyuan (MOST) and Dr Jiangang Li (ASIPP)

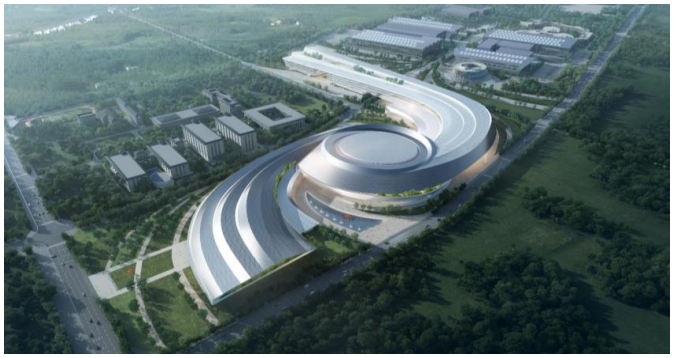


China (2 of 2)

BEST

- Site selectd in March 2019
- First plasma in 2027
- Burning plasma with Q<5
- Steady-state with Q>1
- R = 3.6 m
- a = 1.1 m





Takeaways

No official national fusion strategy or roadmap.

However, toady China is probably the country with the most “aggressive” fusion development program.

Key player is ASIPP, with a clear strategy-roadmap: EAST-BEST-CFETR.

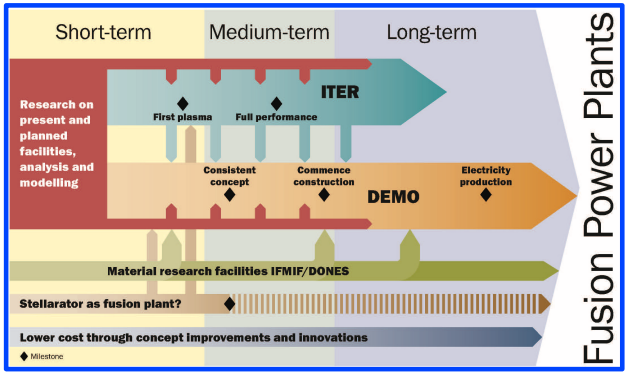
Other players should not be understimated, even if their strategy/roadmap is currently unclear.

EU (1 of 2)

EU has a Roadmap but not a Strategy! However:

- COM study on potential public-private partnership approach to foster innovation in fusion energy (7/03/2024)
- European high-level roundtable on fusion energy (14/03/2024)
- Interim Evaluation of EURATOM Fusion Program 2021-2025 and Ex-ante Assessment of Extension of EURATOM Fusion Program 2026-2027
- Mario Draghi Report on the future of European colmpetitiveness: we need to create 'a stable and predictable fusion ecosystem for industrial innovation, leveraging the ITER project, while ensuring a clear technology development roadmap.' (Sept. 2024)
- COM Fusion Expert Group (KO meeting 26/06/2024)
- EU Parliament plenary session on energy (22/01/2025): a majority of MEPs called for the opportunity of nuclear fusion to be grasped to ensure the European Union's industrial competitiveness and energy sovereignty in the future.

A strategic document from COM expected to be published in 2025.



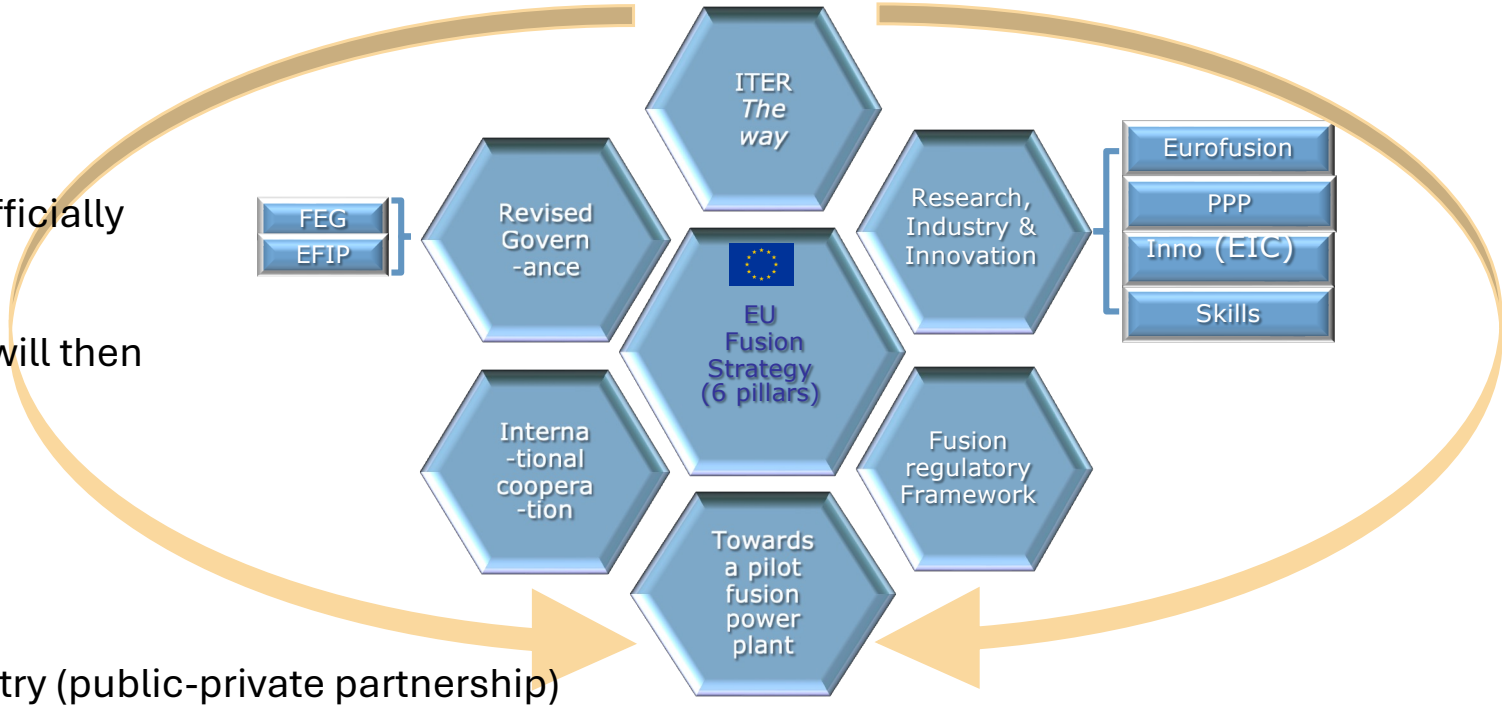
Thanks to Dr Elena Righi (Europea Commission, RTD.D.4)

EU (2 of 2)

Takeaways

An EU fusion strategy should be officially published in 2025.

The EUROfusion fusion roadmap will then have to be revised.



Key changes:

- Stronger involvement of industry (public-private partnership)
- Reinforced international cooperation
- New governance

The EU programme is entering into a "transition phase", the new structure to implement the forthcoming EU fusion strategy should be fully in place by end 2026

Comments

The main lines or research in MCF are tokamaks and stellarators, with strong supporters for both in EU, US and the private sector. UK is focusing on the spheromak; Japan on the tokamak. ICF is still a contender to MCF.

Before DEMO/CFETR/pilot plant, only few devices are planning to use DT in the future: BEST and ITER in particular, the VNS if it is confirmed, SPARC in small quantities.

Identical keywords/key statements are used in the different strategies (reinforce INCO, develop PPPs, etc.), but they are then developed considering the specificities of each country.

Most countries aim to develop a strong national industrial base to compete successfully in the emerging fusion business.

Still many benefits in a stronger INCO. Suitable instruments to do so exists, e.g., the IEA Technology Cooperation Programmes and other multi- and bilateral cooperation agreements. Whether these are suitable for cooperation with industry remains to be confirmed.

Conclusion – Key Questions

Key questions on the different strategies (a personal view):

- US – Is it too early to implement the shift from publicly-led RD&D to privatly-led initiatives?
- UK – Too small to do it alone; with whom will it collaborate?
- Japan – The strategy “ITER-DEMO-Fusion Power Plant” is less and less credible. Will their future roadmap recognise it?
- China – China is coming!
- EU – Will it be able to implement our future strategy efficiently? Will EU industry be up to the challenge?
- IEA – Should the agency strengthen its role in the development of fusion energy?

Thank you for your attention