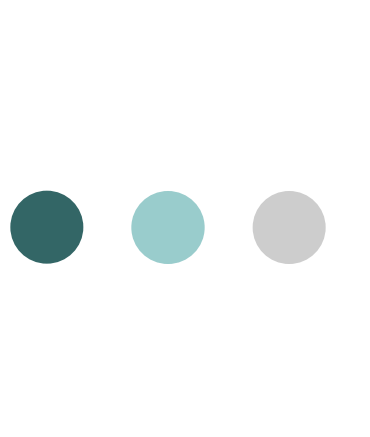
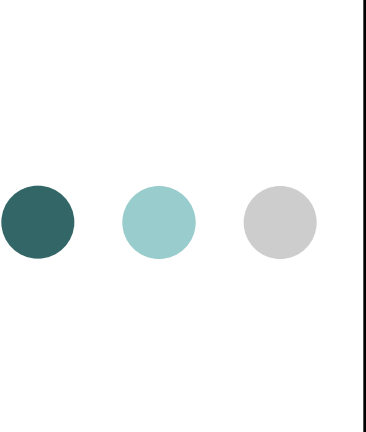




From ITER to Demo -- Technology Towards Fusion Power

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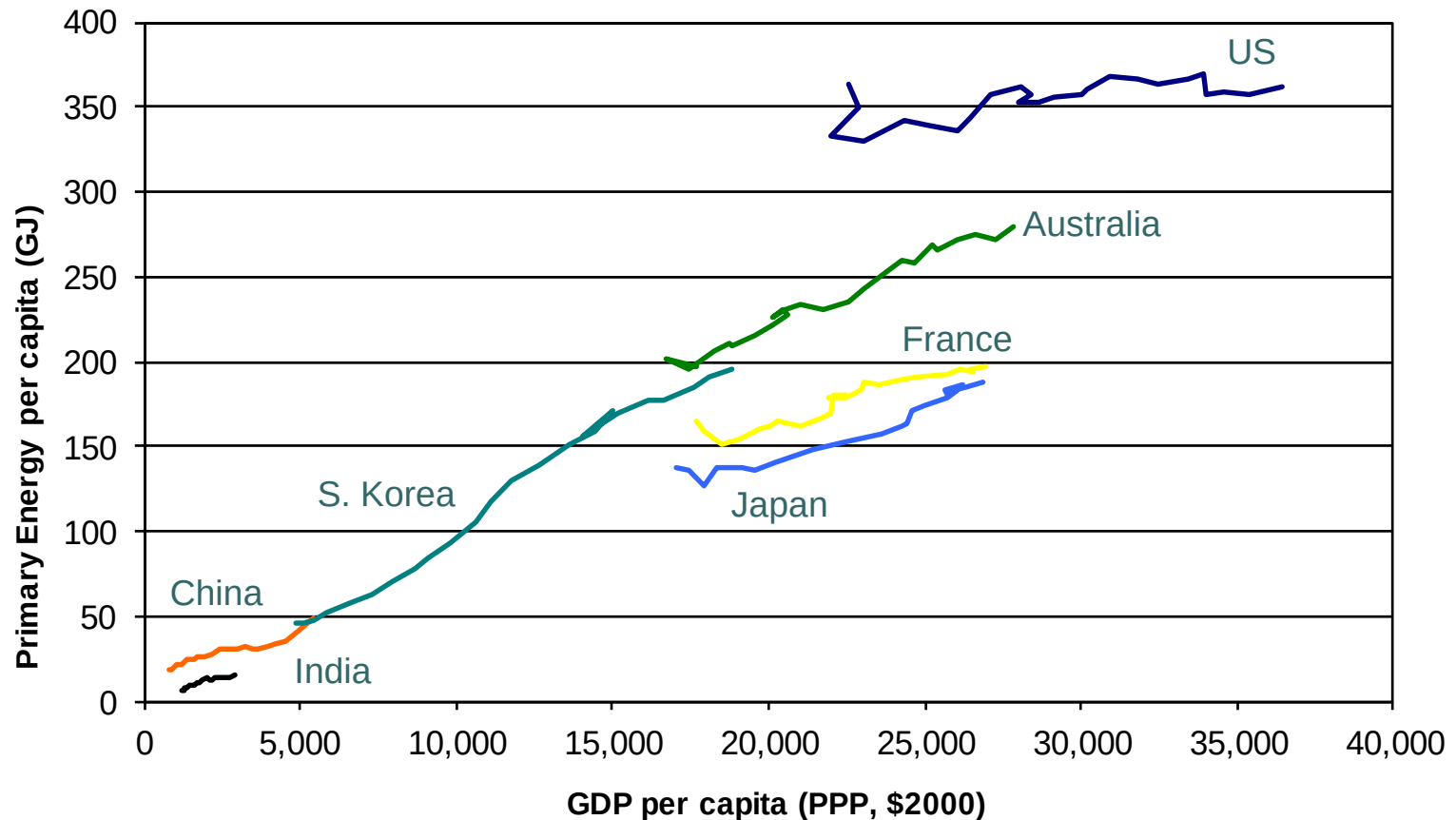
TOFE Panel on Fusion Nuclear Sciences
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Is there a case for a “unified” international road-map for fusion?

Rationale for fusion development
varies substantially around the world.

“World” needs a lot of energy!

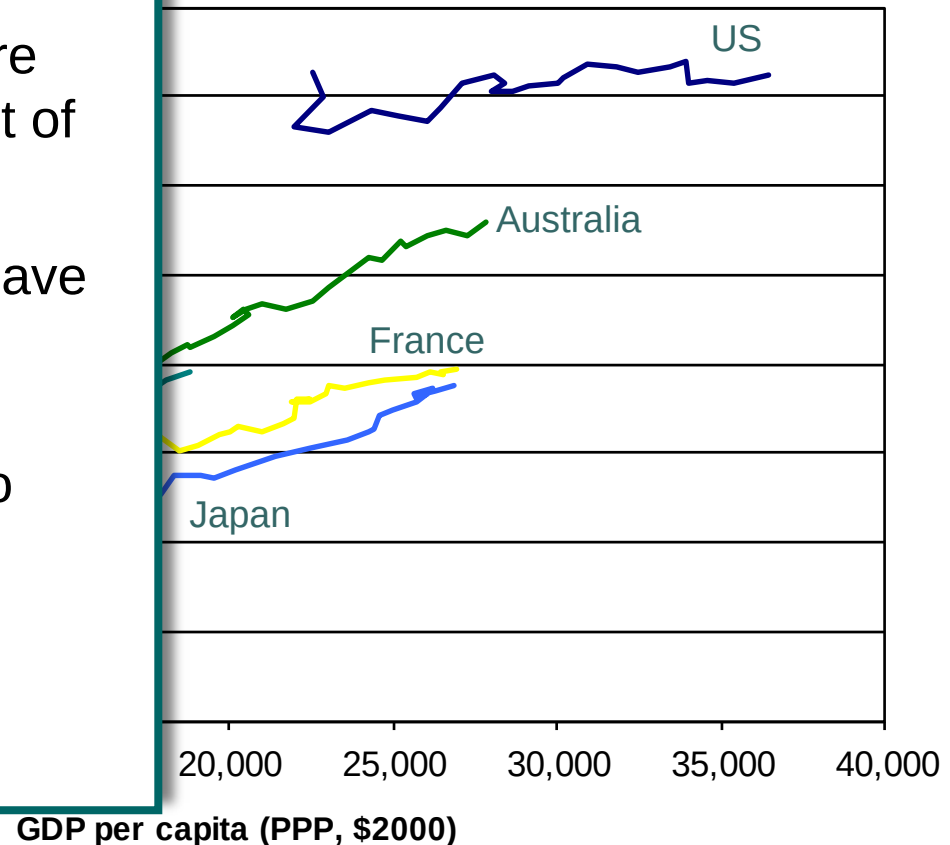


- With industrialization of emerging nations, energy use is expected to grow ~ 4 fold in this century (average 1.6% annual growth rate)

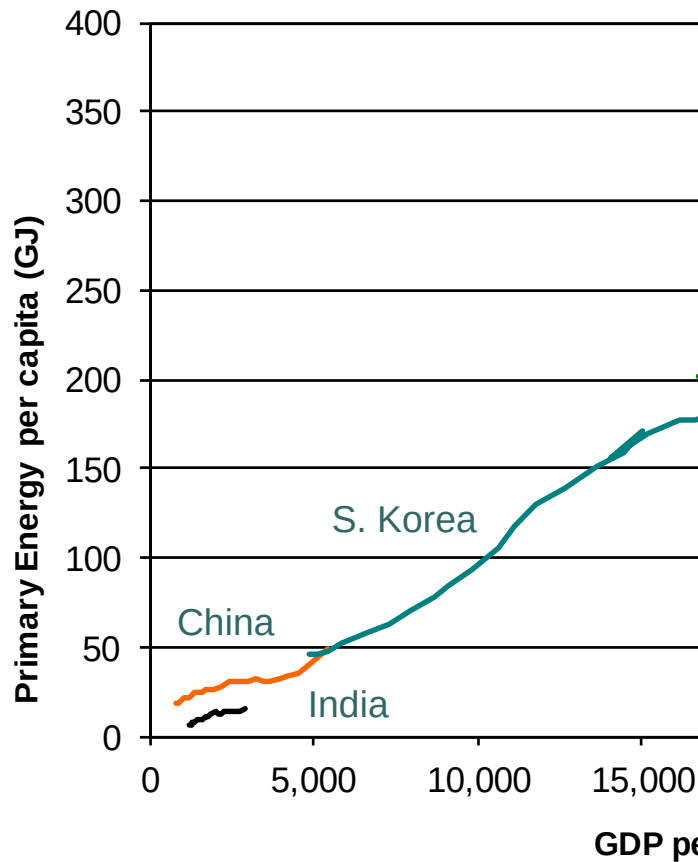
“World” needs a lot of energy!

US, EU, Japan:

- Electricity supply needs are mainly for the replacement of existing power plants.
- Government regulations have been driving the choice of energy supply.
- Different level of access to indigenous fossil fuels for electricity production.
- Different socio-political atmospheres.



“World” needs a lot of energy!



China, India, (S. Korea), ...

- Large supplies of Electricity is needed to maintain economic growth.
- Governments actively following policies to expand energy supply.
- Different level of access to indigence fossil fuels for electricity production
- Different socio-political atmospheres.



While current rationale for R&D differs, the ultimate goal would be the same.

- Fusion R&D expenditures are justified to government agencies who have different priorities and, therefore, respond to different “Roadmaps.”
 - Different R&D plans for the next decade.
- However, large-scale (multi-billion \$) fusion facilities beyond ITER and NIF can only be justified in the context of their contribution to energy supply , i.e., commercial fusion.
 - Fusion roadmaps should include all R&D needed to achieve commercial fusion power.
- We will also have
 - Different Customers (e.g., Power Producers)
 - Different criteria for success (e.g., Commercial viability)
 - Timing (e.g., Is there a market need?)



Fusion Energy Development Focuses on Facilities Rather than the Needed Science

- Current fusion roadmaps which focus on “Demo” have a high probability of leading to lengthier and costlier programs (for commercial fusion).
 - Mission will be redefined to fit the “promised” time frame.
 - Cost, available data base, etc. will lead to further mission contraction, expanding the R&D needed after the next step and may also to un-necessary R&D.
- Recall ITER history (proposed in mid-80s, many revision of its mission, considerable expenditure, ...).

This is in contrast with the normal development path of any product in which the status of R&D necessitates a facility for experimentation.



Developing Fusion Power Technologies (FNS)...



Developing commercial fusion energy requires changes in our folklore:

- Fusion power technologies (fusion nuclear sciences) are in their early stages of development. We are NOT ready!
- Development of fusion nuclear sciences requires a large amount of resources.
 - We readily talk about multi-billion-\$ plasma-based facilities but frown at \$1B price tag of IFMIF.
- The perception that the only way to develop fusion nuclear technologies is to have 14-MeV neutrons is not correct (cook and look approach is very expensive and time-consuming)
 - A large portion of R&D can and should be performed in simulated environments (non-nuclear and/or fission test).
 - Fusion nuclear testing is needed only to validate the predicted performance plus all synergetic effects that were not foreseen.
 - 14-MeV neutron sources are NOT equal.



We should focus on developing a technical roadmap

A detailed technical Road Map based on TRL methodology

- Includes what needs to be done (both critical and “non-critical”)
- Highlights the order they need to be done
- Includes clear mile-stones or check points showing progress
- Provides the justification for and the mission of needed facilities
- A times-less exercise that needs updating

Such a Technical Roadmap provides the technical basis to develop policies and program portfolio.

- Allows flexibility in implementation scenarios (aggressive or slow)
- Allows multi-year program planning
- Provides a firm basis on cost/benefit analysis
- Provides a mechanism for “coordination” internationally and with plasma physics research.



Framework for technical roadmap

- Phase 1: Achieve TRL level 4 for all components (“Component and/or bench-scale validation in a laboratory environment”)
 - Examples: demonstration of thermo-mechanical response of a blanket and divertor unit-cell, tritium extraction system in lab scale, fundamental material property demonstration and optimization.
- Phase 2: Achieve TRL level 6 for all component (“System/subsystem model or prototype demonstration in relevant environment.”)
 - Examples: demonstration of an integrated full scale blanket/divertor module/sectors in non-nuclear (simulated environment). Demonstration of blanket/divertor unit-cell in fission environment.
- Phase 3: Achieve TRL level 7-8 for all components (“System prototype demonstration in an operational environment”)
 - Example: Validation in a fusion nuclear facility. Resolution of synergetic effects.



In summary ...

- We need to develop a fusion energy technical roadmap (“Fusion Nuclear Sciences” road-map).
 - Large-scale facility should be only validation facilities.
 - Required science and engineering basis for any large facility should be clearly defined and included in such a Road-map.
 - We need to start implementing such a road-map to show that we are serious (only the “pace” is set by funding).
 - We need to start work-force development.
- Increased funding and emphasis for fusion have always been driven by external factors.
 - We need to be prepared to take advantage of these opportunities.
 - It is possible to field fusion power plant before 2050, but we lay the ground work now!



Thank you!