Future Nuclear – do we need Generation IV or Fusion?

Steve Cowley

Do we have the technology we need for the future energy supply?

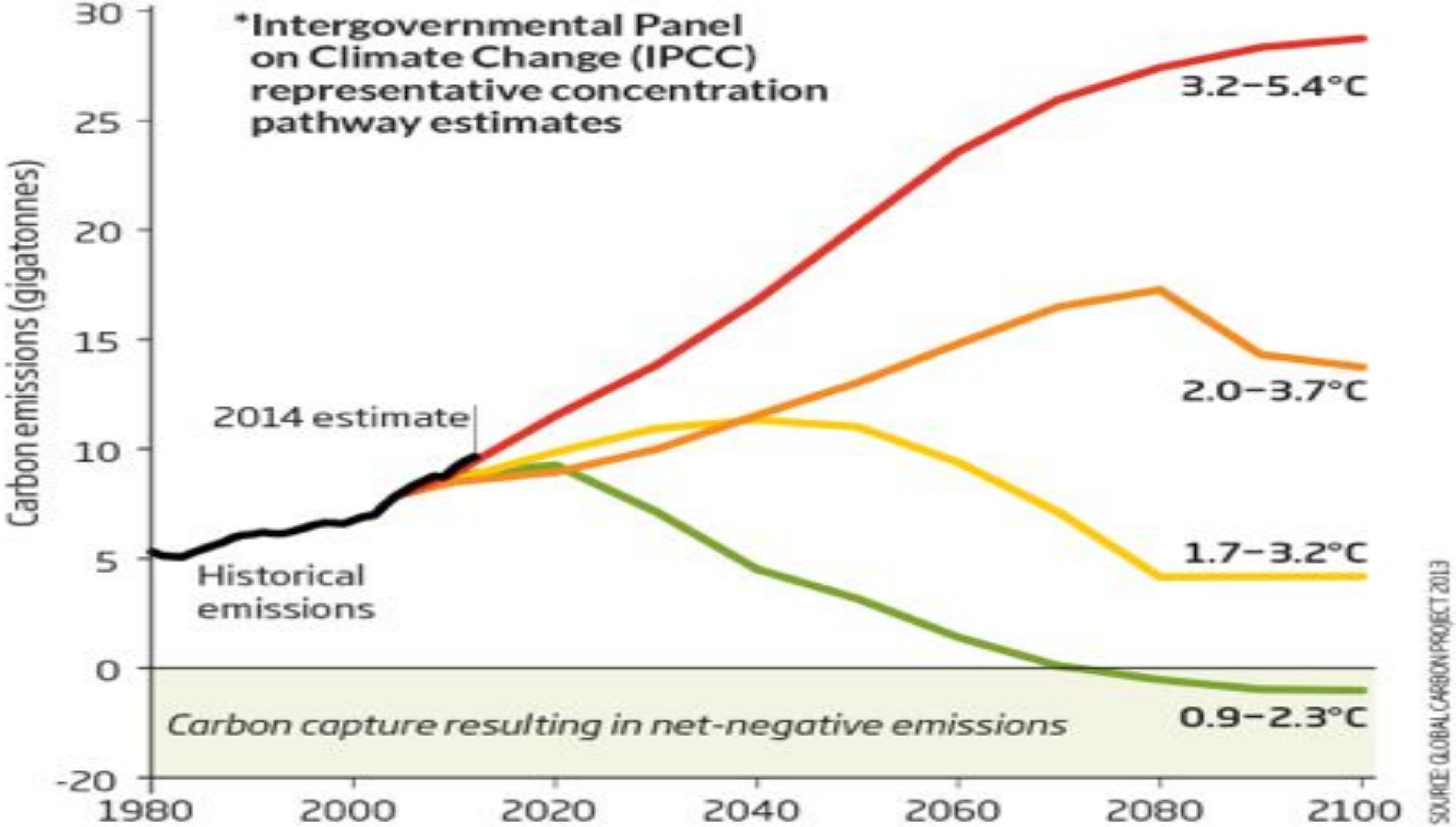
If not what do we have to do?

For when?

I will mainly focus on nuclear as a supply option. The same questions can be asked much more generally.

Emissions go from bad to worse

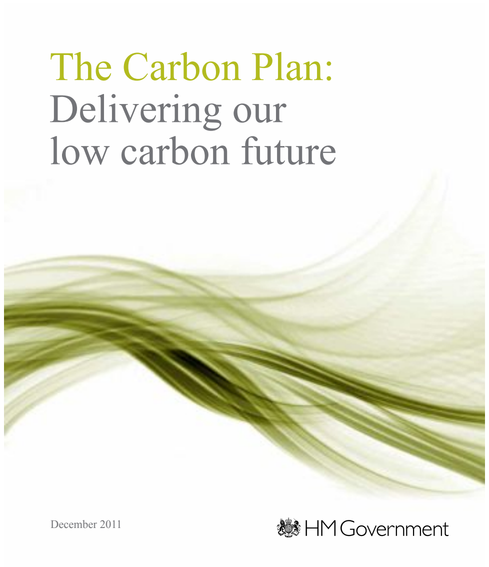
The new report from the Global Carbon Project shows global emissions are following the course of the worst of four scenarios*. This suggests warming of at least 3°C by 2100, relative to 1850-1900



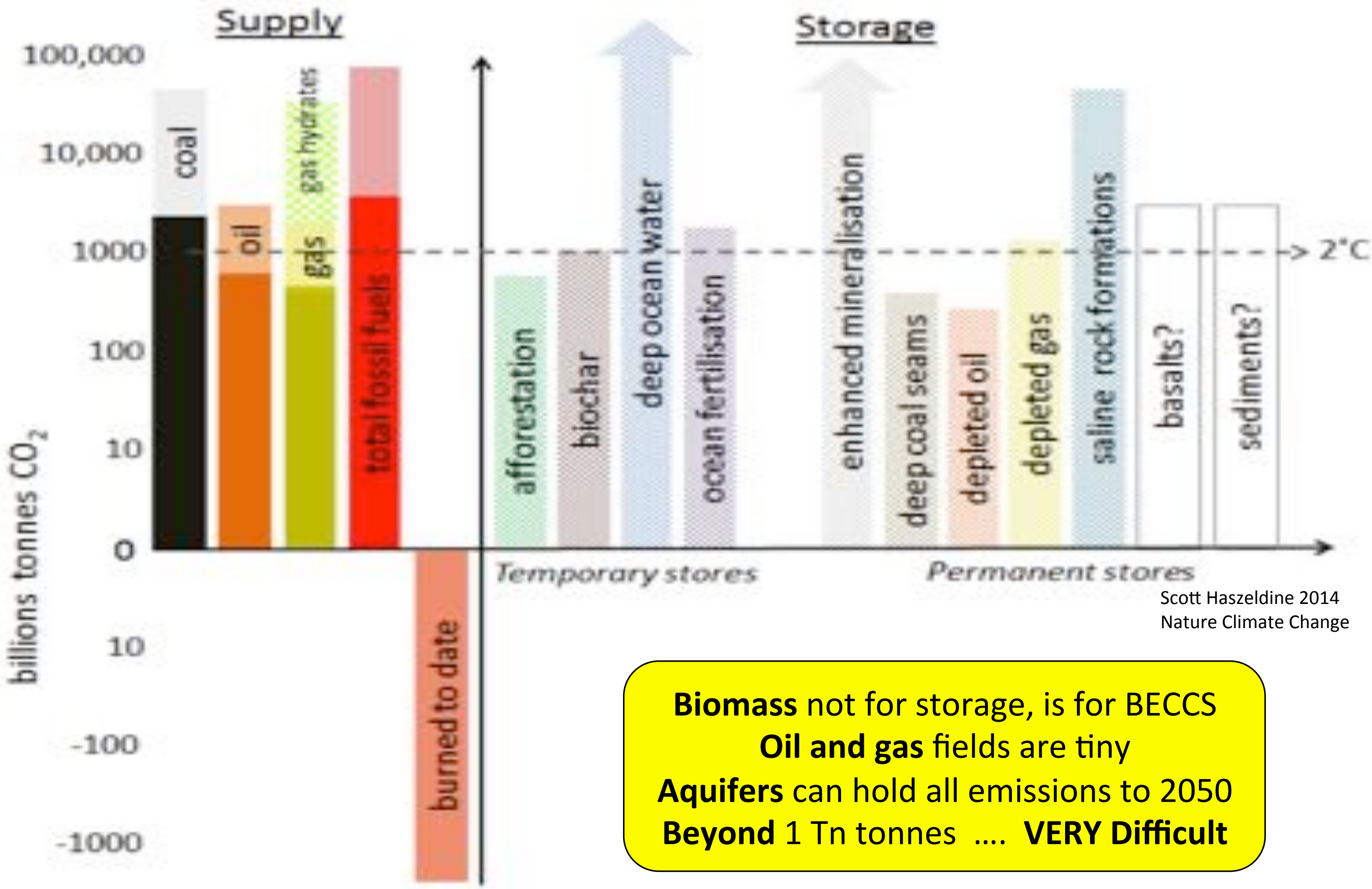
40 billion tonnes of CO_2 will be emitted this year.

(All figures in 2050)	Measure	Core MARKAL	Renewables; more energy efficiency	CCS; more bioenergy	Nuclear; less energy efficiency
Energy saving per capita, 2007–50		50%	54%	43%	31%
Electricity demand increase, 2007–50		38%	39%	29%	60%
Buildings	Solid wall insulation installed	n/a[16]	7.7 million	5.6 million	5.6 million
	Cavity wall insulation installed	n/a[16]	8.8 million	6.9 million	6.9 million
	House-level heating	92%	100%	50%	90%
	Network-level heating	8%	0%	50%	10%
Transport	Ultra-low emission cars and vans (% of fleet)	75%	100%	65%	80%
Industry	Greenhouse gas capture via CCS	69%	48%	48%	0%
Electricity generation	Nuclear	33 GW	16 GW	20 GW	75 GW
	CCS	28 GW	13 GW	40 GW	2 GW
	Renewables[17]	45 GW	106 GW	36 GW	22 GW
Agriculture and land use	Bioenergy use	~350 TWh	~180 TWh	~470 TWh	~460 TWh

DECC 2011 report 2050 scenarios



GeoEngineering CDR Global carbon storage



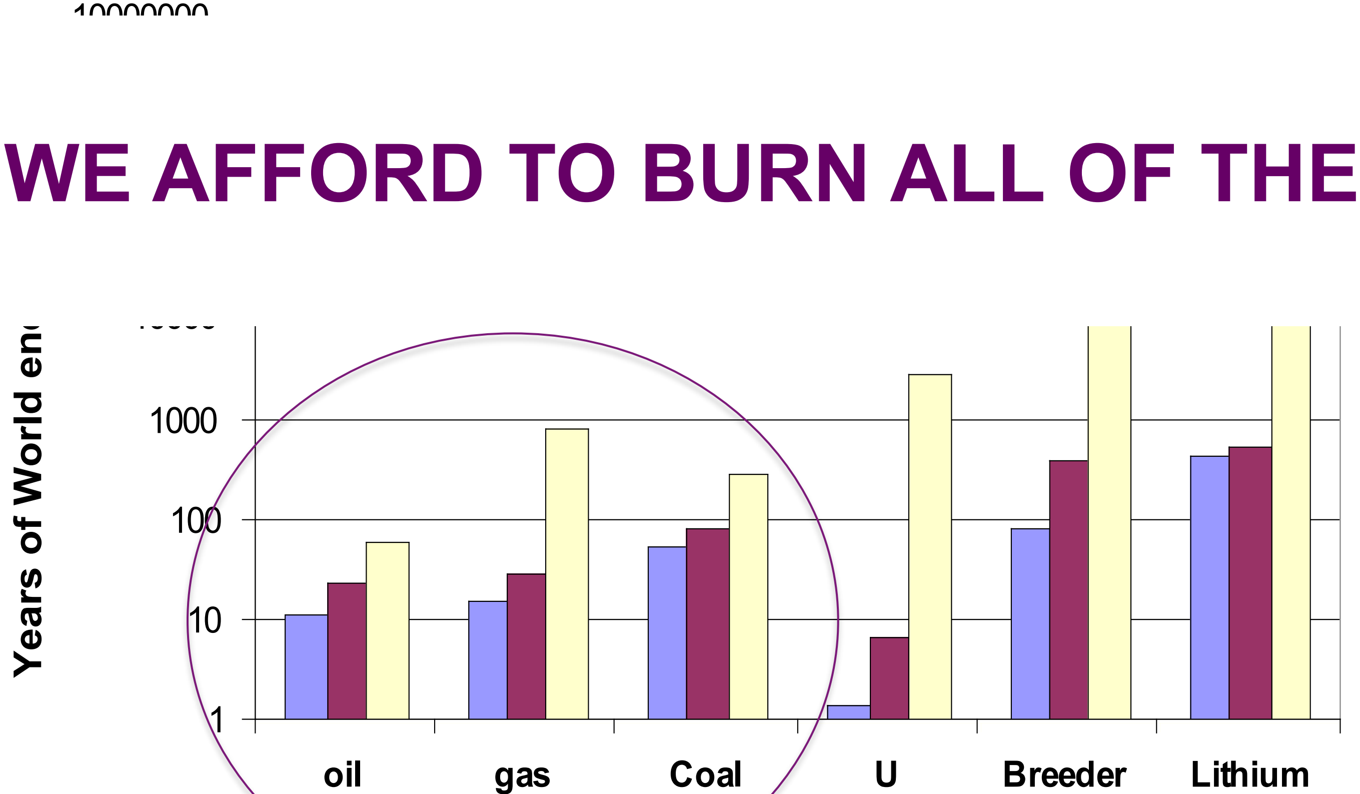
Scott Haszeldine 2014
Nature Climate Change

Biomass not for storage, is for BECCS
Oil and gas fields are tiny
Aquifers can hold all emissions to 2050
Beyond 1 Tn tonnes …. **VERY Difficult**

Ultimate fuel resource for different energy systems

David Ward

CAN WE AFFORD TO BURN ALL OF THESE



Large resources in coal, fission breeder and fusion. Solar provides a large resource as well. Source: WEC, BP, USGS, WNA

World Energy – a three stage problem

Stage 1. 2015-2024 Keep the lights on. Renew grids, renew generation, secure gas supply .....

Stage 2. 2024 – 2100 Carbon emissions reduction, Transitional Technologies. Nuclear, coal -> gas, carbon capture and storage (CCS), grow renewables, CONSERVE, CONSERVE.

Stage 3. 2100 -- ..... Sustainable low carbon supply. Replace all fossil fuels without conventional nuclear and CCS. Land use limited. **Renewables (solar) + ……… Advanced nuclear and fusion.**

UK Nuclear Plan?

New Build – once through fission
Hinkley Point

"Make some money before we worry about future nuclear"

Probably a pragmatic strategy

Aim is to install 16GW conventional nuclear – probably 80 year lifetime.

3.2GW from two EPR reactors

UK Atomic Energy Authority

UK - Long-term Nuclear Energy Strategy 2013

"Within 3 of the 4 key Carbon Plan scenarios, nuclear energy is envisaged as delivering a much larger amount of generation than that available now, with the potential to deliver up to 75GW of the UK's energy needs.

In order to potentially deliver against the upper end of this scope it is likely that more advanced and diverse options will need to be explored in terms of nuclear technology.

Such options may include: **development of newer fission technologies such as evolutionary LWR's, small modular reactors (SMRs) or Generation IV ; options for closing the uranium fuel cycle and reprocessing spent fuel; progressing the development of fusion; and consideration of alternative fuel cycles.** Ensuring that these options are not foreclosed or essential skills lost will be an important long term objective".

The debate goes on …..


Sir Christopher Hinton

1947, 1950, reports from Harwell by R.V. Moore on economics of nuclear power. "170 different kinds of reactor"

- Recognition that breeders were needed in the long term because of limited Uranium supply. Technology was not ready, safety not understood. But compact high energy density systems -- ultimately attractive economically.

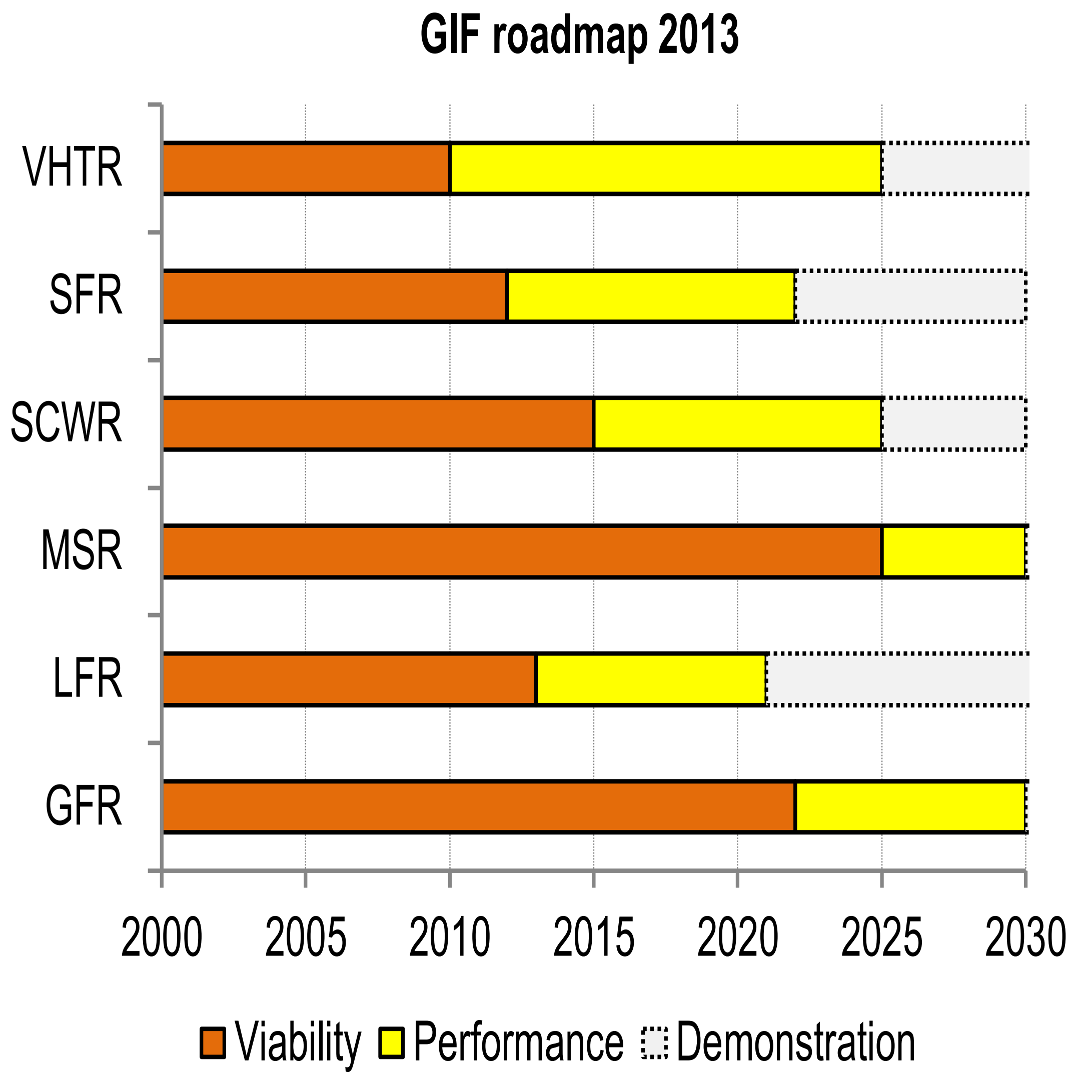
- Natural uranium reactors – near term, supply energy and Plutonium. "Not competitive with coal" but military need. Large low power density. Calder Hall etc. MAGNOX.

- Enriched uranium reactors – enrichment was too expensive in 1950. More compact. Today's reactors – enriched to 3-5% -- enrichment is relatively cheap.

- First UK breeder (DFR) opened 1959, Dounreay Scotland. Last one (PFR) closed in 1994.

Generation IV -- Nuclear

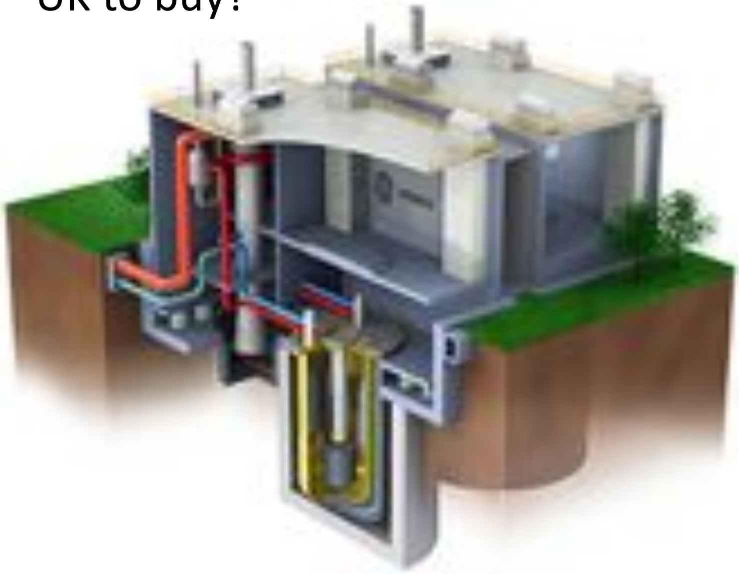
- very-high-temperature reactor
- sodium-cooled fast reactor;
- supercritical-water-cooled reactor;
- molten salt reactor;
- lead-cooled fast reactor);
- gas-cooled fast reactor;



Sodium Cooled Fast Reactor

BN600 operational
Sodium cooled
Fast reactor. 560MW
Oblast -- Russia.

PRISM – US GE/Hitachi
Reactor – plutonium burner
UK to buy?



PROPOSED

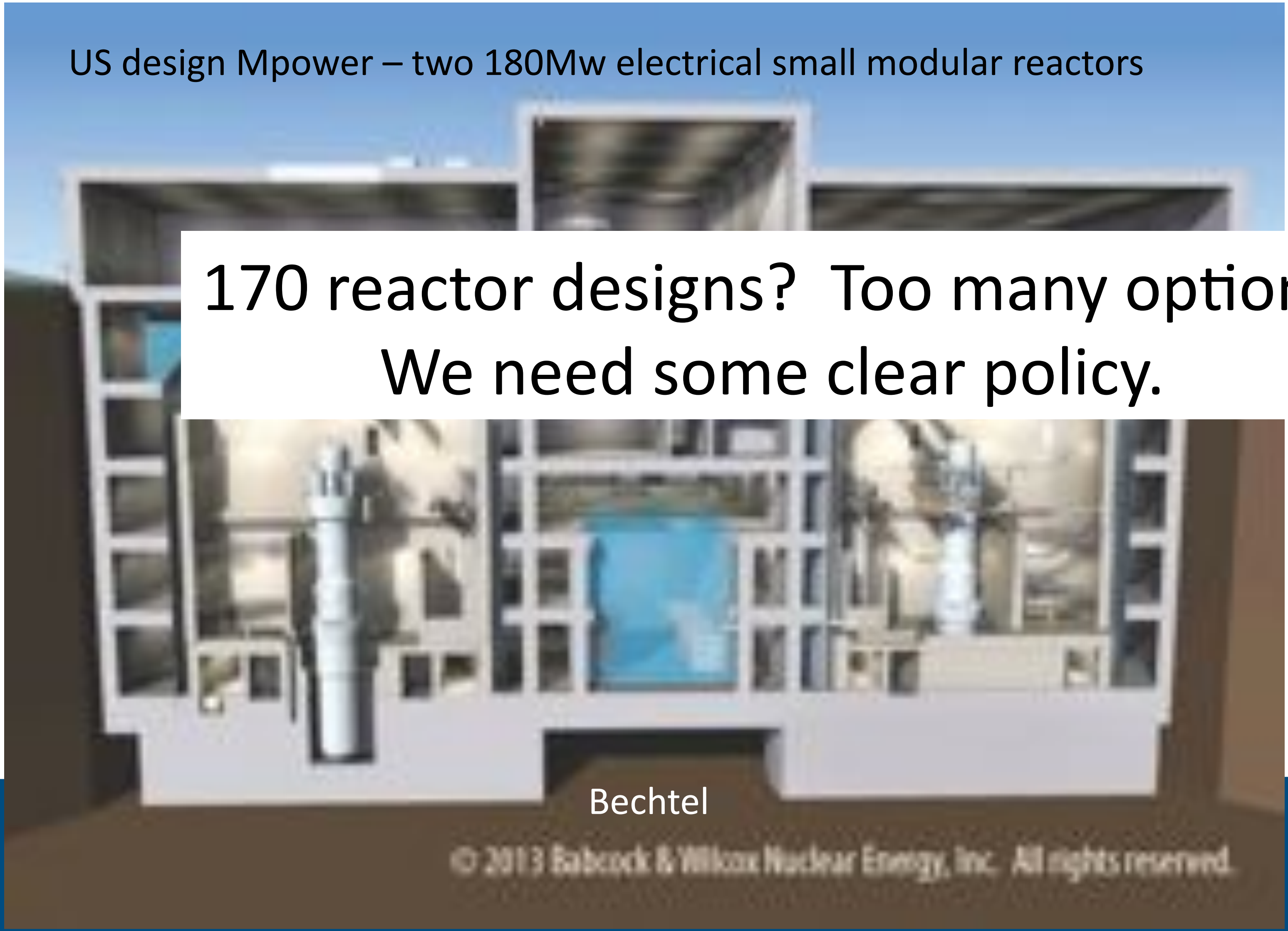
ASTRID – French, EDF/AREVA
Fast reactor UK involvement?

Architecture with internal vessel with conical inner vessel (redan)

Small Modular Reactors – build in Factory exploiting advanced manufacturing.

We have capability in UK – supply chain, factories and design. Should we build them? Decision process underway.

US design Mpower – two 180Mw electrical small modular reactors



170 reactor designs? Too many options
We need some clear policy.

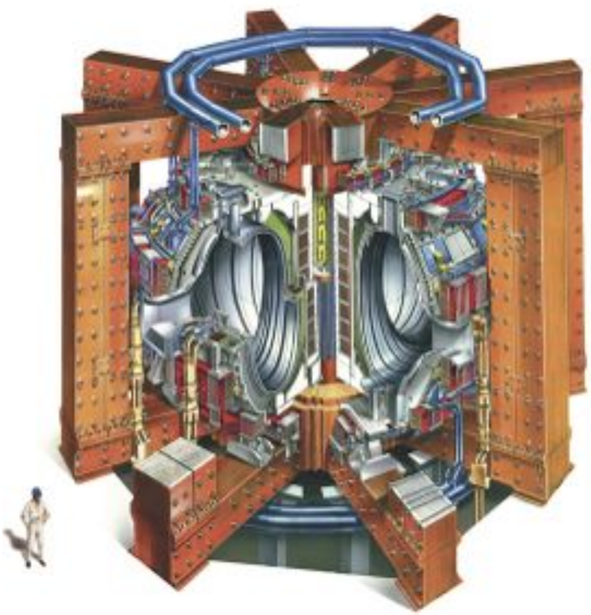
UK Atomic Energy Authority

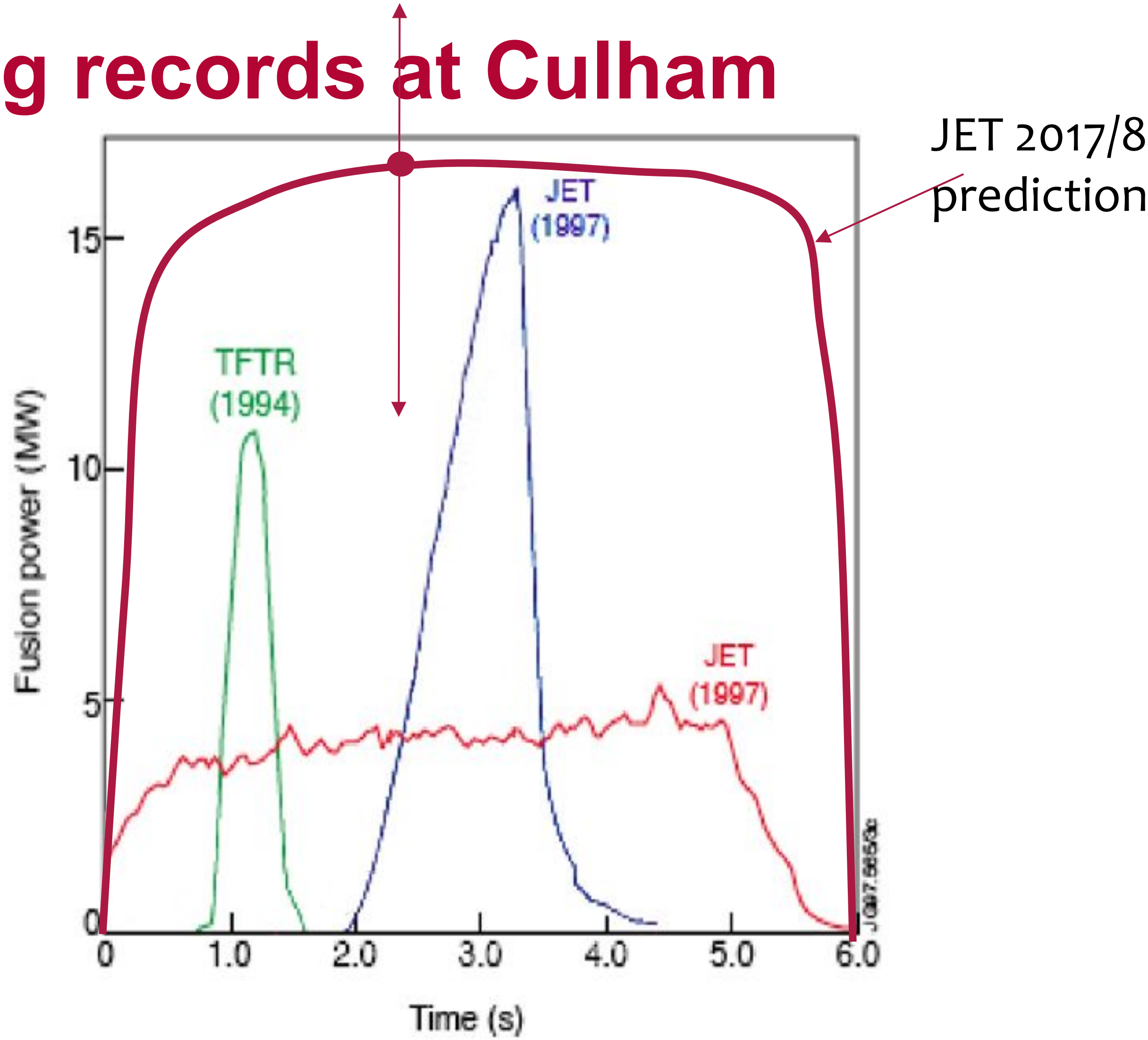
What about fusion – when is it going to produce electricity?

EU roadmap to deliver first electricity before 2050


CP11J-047-27

Breaking records at Culham





Currently the only machine capable of fusion

UK Atomic
Energy
Authority

ITER

First sustained burning plasma.

Starts in 2020.

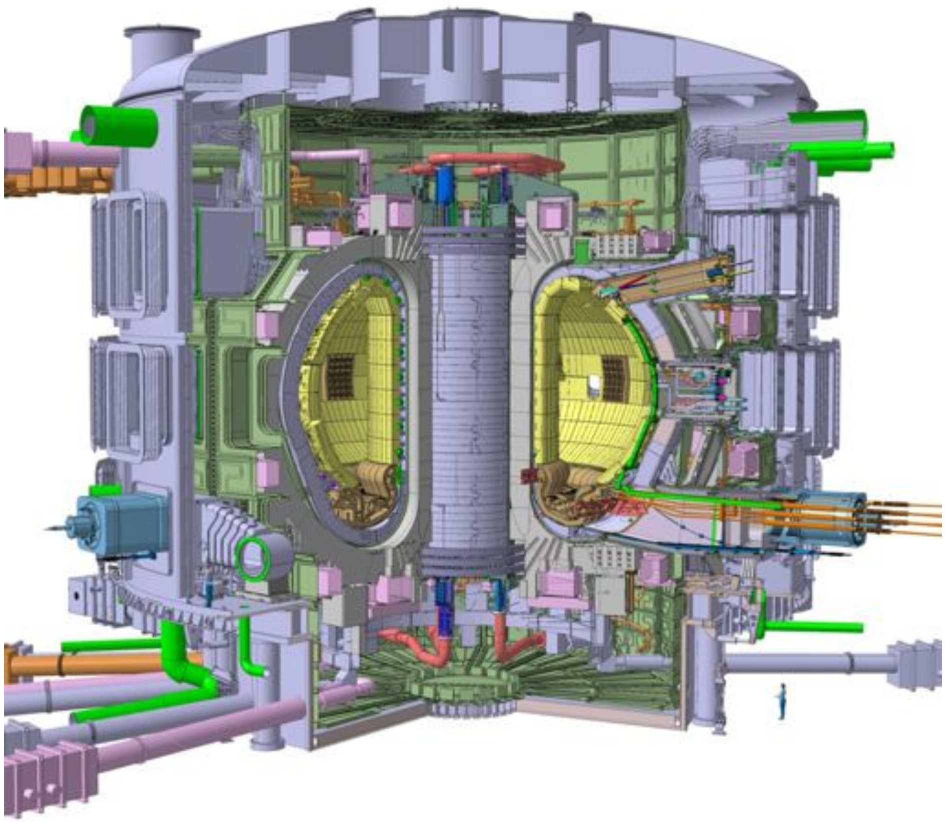
BASIC PARAMETERS:

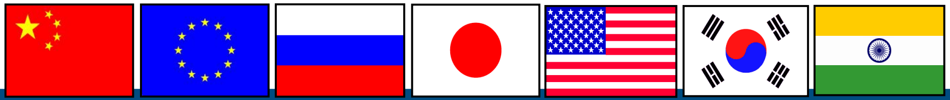
Fusion Power 500MW

Burn Flat Top >400s

Power Amplification Q>10

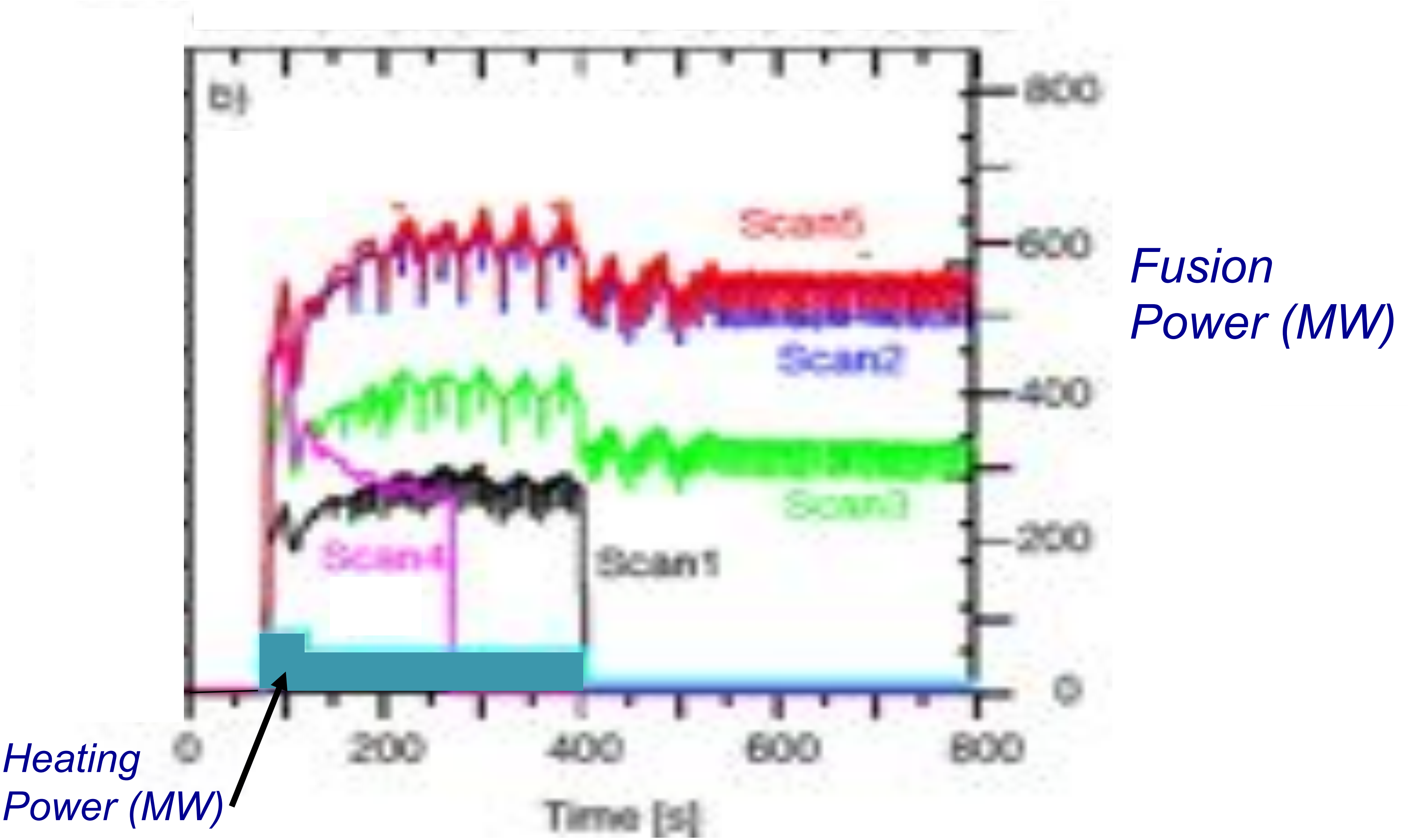
Cost is > 12 Billion Euro.



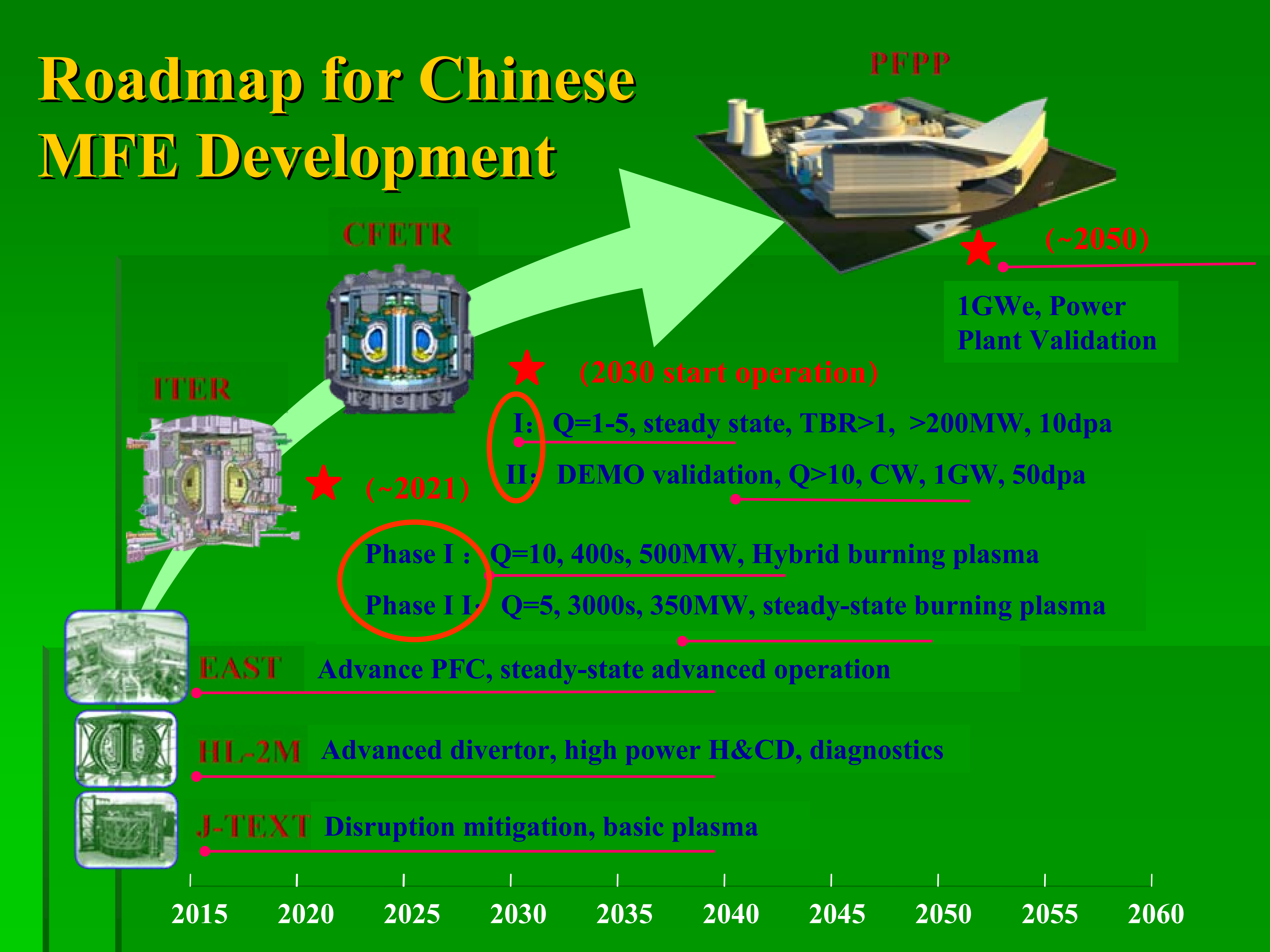


ITER Computer Modeling

Budny 2009



EU Demonstration Reactor – start 2040-5.


Roadmap for Chinese MFE Development
PFPP
(~2050)
1GWe, Power Plant Validation
CFETR
(2030 start operation)
I: Q=1-5, steady state, TBR>1, >200MW, 10dpa
II: DEMO validation, Q>10, CW, 1GW, 50dpa
ITER
(~2021)
Phase I : Q=10, 400s, 500MW, Hybrid burning plasma
Phase I I: Q=5, 3000s, 350MW, steady-state burning plasma
EAST
Advance PFC, steady-state advanced operation
HL-2M
Advanced divertor, high power H&CD, diagnostics
J-TEXT
Disruption mitigation, basic plasma
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060

Not very clear?

- If Nuclear is to play more than a transitional role we have to do R&D.

- There is no consensus about Generation IV projects:
    - No priority
    - Technical issues are cloudy -- but some technology has been prototyped
    - "The market will decide"

- Fusion has a clearer path – perhaps because we are further away.