Analysing the Role of Fusion Power in the Future Global Energy System

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ANALYSING THE ROLE OF FUSION POWER IN THE FUTURE GLOBAL ENERGY SYSTEM

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MODEL DESCRIPTION

The EFDA Times Model (ETM) 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

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 provided by IEA-ETSAP (IEA Energy Technology Systems Analysis Programme Implementing Agreement)

First version was produced in 2002. Last version in 2012

ETM participants are EURATOM Associations

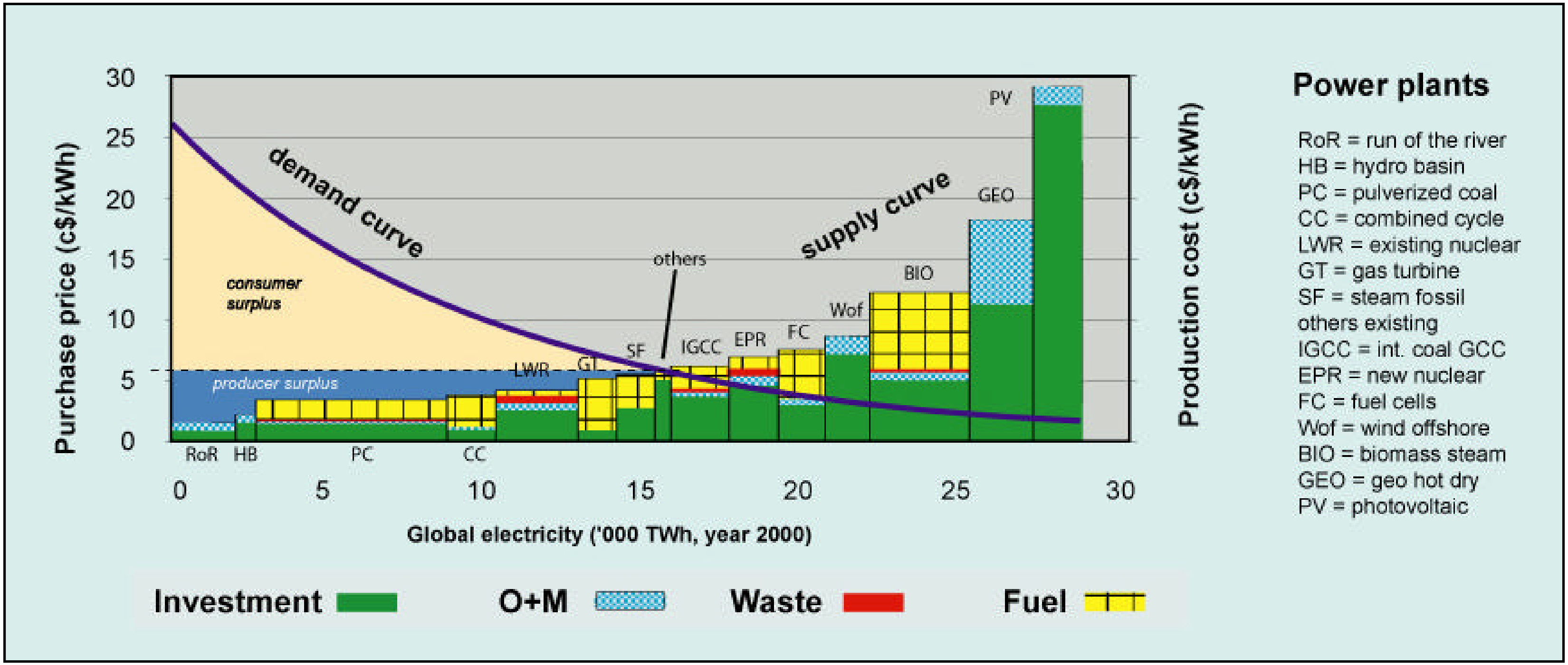
Main ETM objective

“Scenarios are a tool for helping us to take a long view in a world of great uncertainty (ignorance, for me).” "The end result [of a present scenario exercise] is not an accurate picture of tomorrow, but better decisions today [about the future]." [Schwartz, 1996]

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

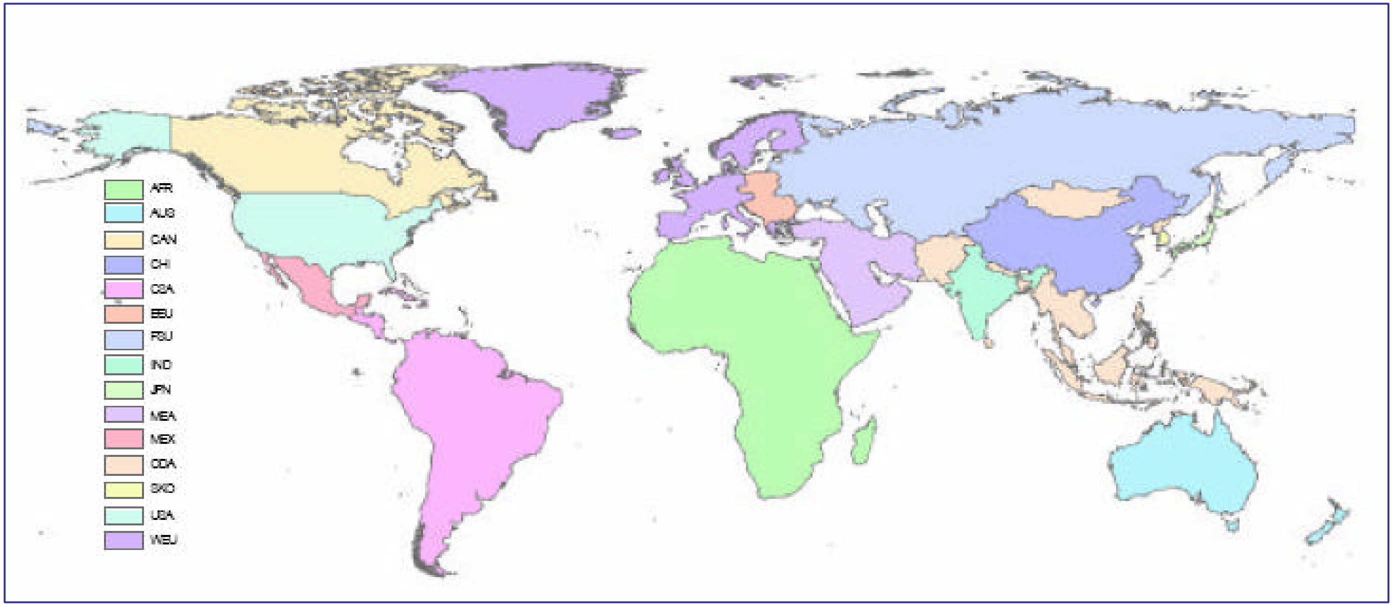
Unlike other global energy models, ETM describes the whole fusion sector from Lithium extraction to electricity production by fusion plants

Market equilibrium



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

Main characteristics



- 15 world regions: Africa, Australia-New Zealand, Canada, China, Central and South America, Eastern Europe, Former Soviet Union, India, Japan, Middle East, Mexico, Other Developing Asia, South Korea, United States, and Western Europe. New version 2012, 18 regions
- 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/downstream
- 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 [1]

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

[1] Han W.S. and Ward D. Revised assessments of the economics of fusion power. *Fusion Engineering and Design* 84 (2009) 895-898

SCENARIOS

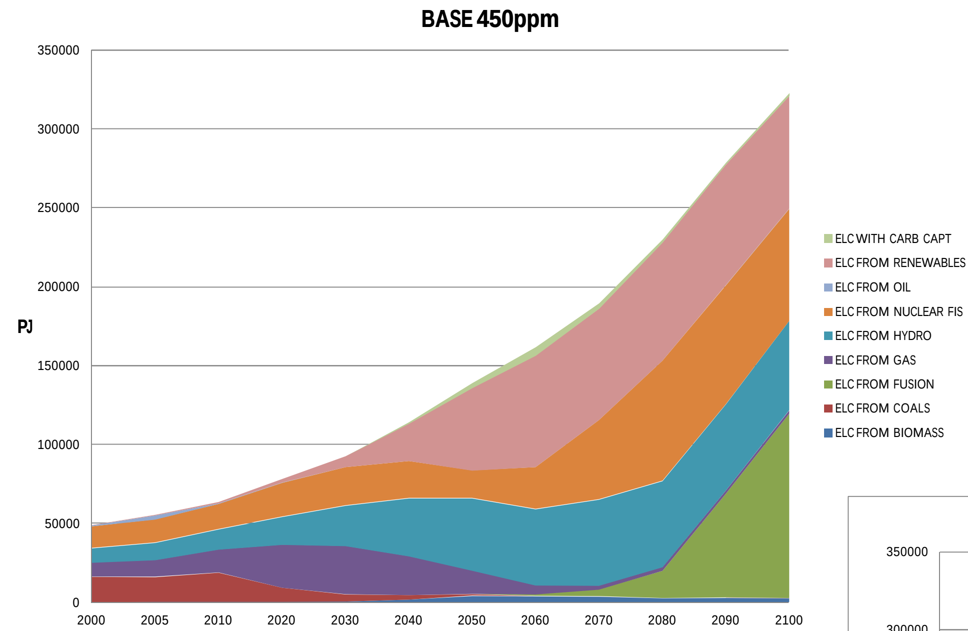
- Base scenario with no environmental constraints
- Base 450ppm scenario with limits by 2100

For the sensitivity analysis

- High growth scenarios
- Tax scenarios

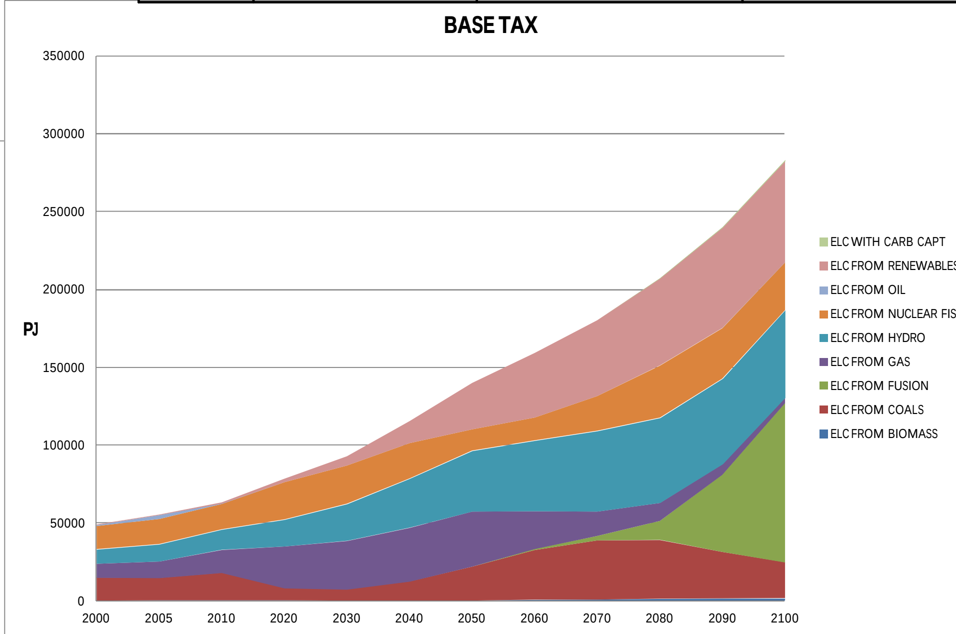
TAXES
- **OECD: 20$/tCO2 in 2020 to 50$/tCO2 in 2100**
- **Non OECD: 10$/tCO2 in 2020 to 25$/tCO2 in 2100**

RESULTS

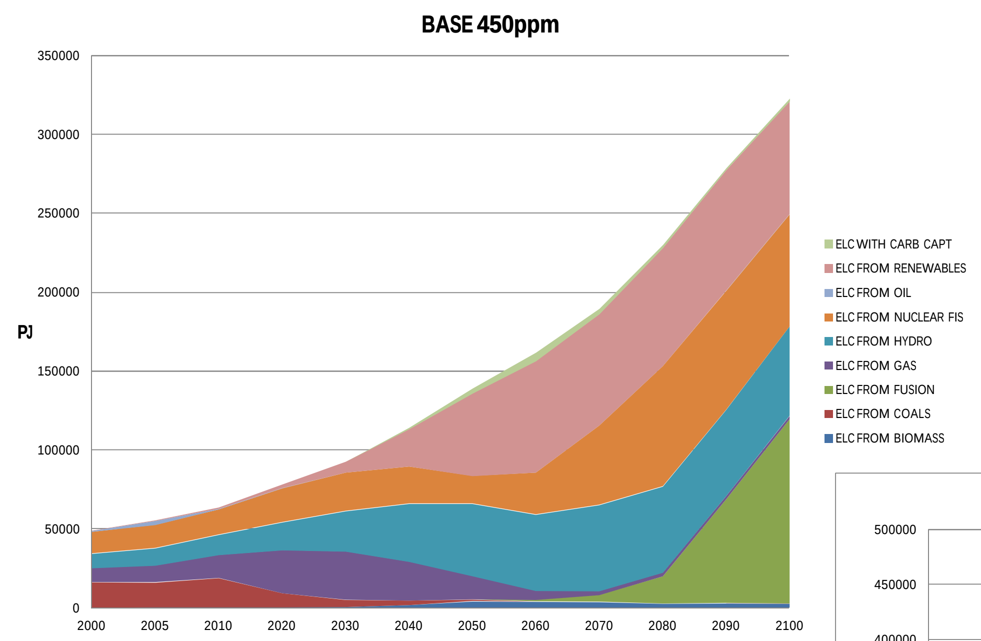


	Base	Base 450 ppm	Base Tax
Fusion	no	**36% in 2100**	**36% in 2100**
Fission	Important from 2040 25% in 2100	Recovers in 2050 22% in 2100	Fluctuate LWR? ABR 10% in 2100
RES	Onshore and hydro 16% in 2100	Increase CSP and offshore 22% in 2100	Increase 23% in 2010
Coal	**Dominant role** **50% in 2100**	Phases out in 2050	Still relevant 8% in 2100
Gas	Decrease from 2050 2% in 2100	Decrease from 2050 1% in 2100	Increases until 2050 Then declines
CCS	no	1% in 2100	neglible

Global electricity generation

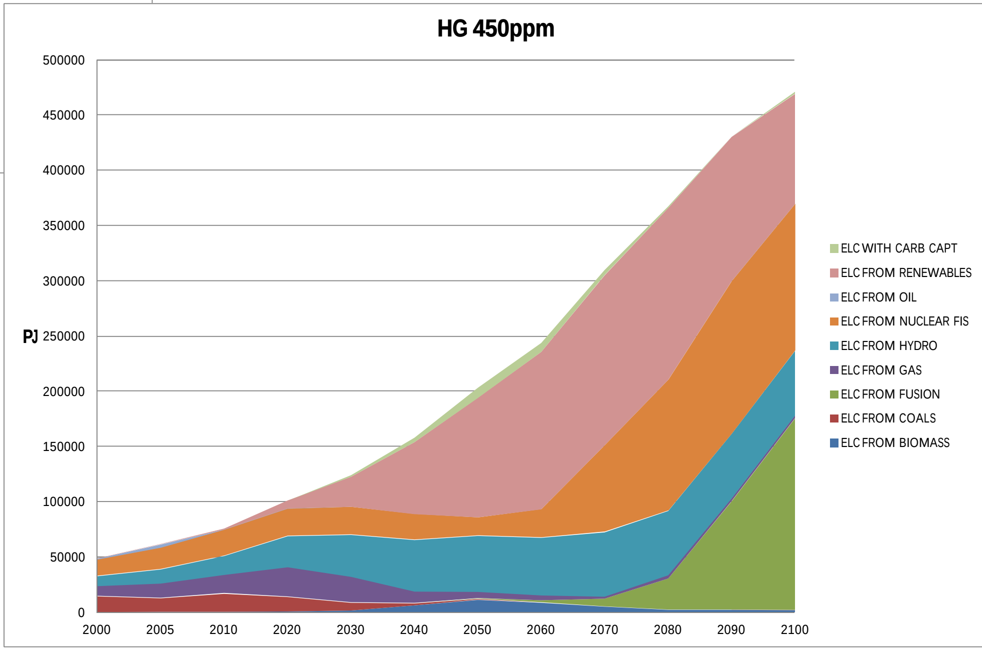


RESULTS



	Base 450 ppm	HG 450 ppm
Fusion	**36% in 2100**	**36% in 2100**
Fission	Recovers in 2050 22% in 2100	Recovers in 2060 29% in 2100
RES	Increase CSP and offshore 22% in 2100	Increase, high CSP 21% in 2100
Coal	Phases out in 2050	Phases out in 2050
Gas	Decrease from 2050 1% in 2100	Decrease from 2050 1% in 2100
CCS	Up to 3% in 2060	Up to 4% in 2050

Global electricity generation



CONCLUSIONS

- In the Base Case scenario, fusion does not enter the energy system, while in the 450ppm it is responsible of 36% of the global electricity production in 2100. A concern for **climate change** is an important key driver for fusion penetration
- Energy system composition is the same under different **development growth** scenarios
- Main **fusion competitors** are advanced fission and renewable technologies
- As a consequence, in the 450 ppm scenarios, CO2 emissions at the end of the period are **half of the emissions** in 2000
- Main difference between using caps or taxes for CO2 mitigation is that coal remains having an important share in the tax scenario due to the low taxes in non OECD countries. Coal competes with fission, but fusion behaves the same
- Regarding the regional distribution of fusion plants, when Advanced plants are available, the technology spreads in **all the regions**, except for Central and South America in the Base 450 ppm scenario

Fusion has a chance in the low carbon energy systems

THANK YOU FOR YOUR ATTENTION!

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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