The possible role of fusion power in a future sustainable global energy system using the EFDA TIMES global energy model

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INTRODUCTION

The EFDA Times model (ETM) has been built in the framework of the European Fusion Development Agreement.

ETM background (2004): ORDECSYS, KanORS, HALOA and KUL [1]

ETM participants are EURATOM Associations: CCFE (UK), CIEMAT (ES), ENEA (IT), IPP (GE), IST (PT), ÖAW (AU), RISO DTU (DK) and VTT (FI)

Special mention to GC Tosato who, while being the EFDA Socio-Economic Office leader, fostered the ETM construction

DESCRIPTION

The EFDA Times Model (ETM) is a multi-regional, global and long-term energy model of economic equilibrium, responsive to energy technology innovations, domestic and international trade energy policies, climate change mitigation and environment objectives.

[1] Ordecsys, KanORS, HALOA and KUL. EFDA World TIMES Model. FINAL REPORT and Annexes (2004)

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.
- Time horizon: 2100
- Six time slices: three seasons (winter, summer and intermediate) and two part of the day (day and night)
- Sectors in the RES: residential, commercial, agriculture, industrial, transportation, electricity production and upstream/downstream
- Demand scenario: energy demand driver projections from the general equilibrium model GEM-E3 [2]
- Trade: inter-regional exchange process (trade of commodities) among the different regions

[2] http://www.gem-e3.net/

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

FUSION TECHNOLOGIES IN THE MODEL

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

Fusion power plants characterization: Power Plant Conceptual Study (PPCS) [3]

[3] EFDA. A Conceptual Study of Commercial Fusion Power Plants. Final Report (2005)

LAST ACTIVITIES

Some tasks carried out from 2004:

- Revision and update of the data included in the upstream, power generation, residential, commercial, industry and transportation sectors
- RES sector update
- Modelling of the natural gas markets of the model
- Prospects for fusion generation: sensitivity analysis and storylines
- Preliminary scoping studies of the role of fusion in the future energy market
- Analysis of global energy scenarios
- Resource potentials update

And also:

Continuous data checking and updating, scenario validation, model testing and assessment of results

SCENARIOS

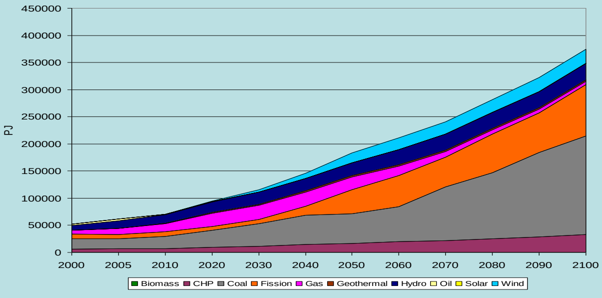
- Base case scenario: there is no limit to CO_2 emissions
- 550ppm scenario: a limit of 550ppm in $CO_{2\text{-eq}}$ concentrations is set by 2100

For the sensitivity analysis

- 650ppm scenario: a limit of 650ppm in $CO_{2\text{-eq}}$ concentrations is set by 2100
- HFC scenario: 550ppm scenario + fusion costs 30% higher
- HUR scenario: 550ppm scenario + high uranium resources (x10)
- ULC scenario: 550ppm scenario + low uranium extraction costs (-50%)

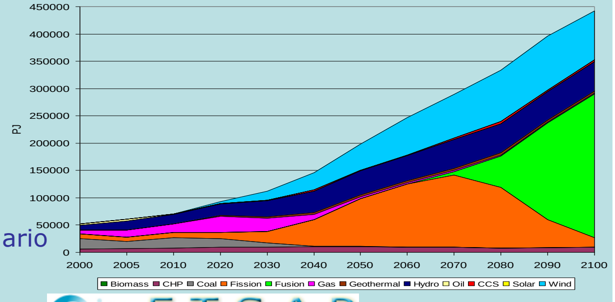
RESULTS- Power Generation

Base case scenario



- Biomass
- CHP
- Coal
- Fission
- Fusion
- Gas
- Geothermal
- Hydro
- Oil
- CCS
- Solar
- WInd

550 ppm scenario



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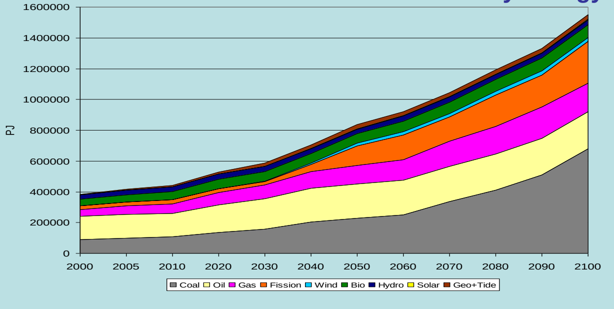
RESULTS- Primary Energy

Base case scenario



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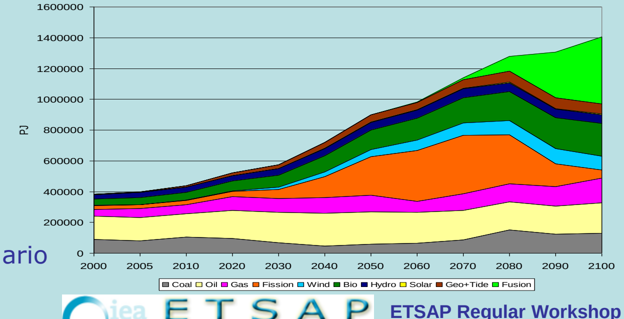
550 ppm scenario



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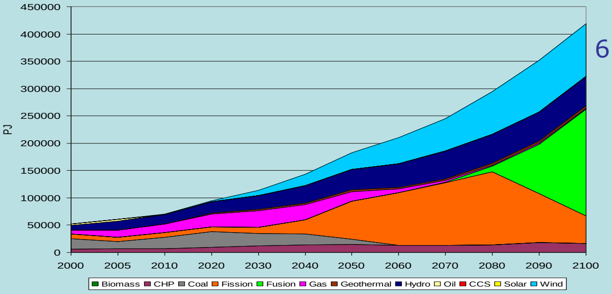
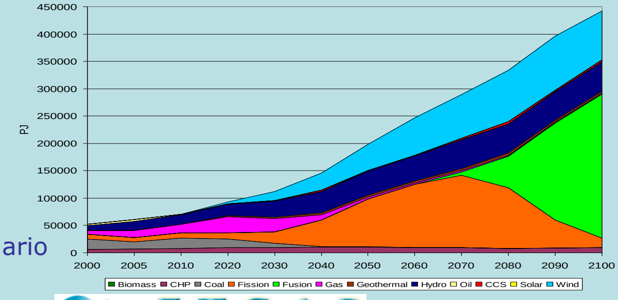
SENSITIVITY ANALYSIS- CO_2 reductions



650 ppm scenario

Power Generation



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- WInd

550 ppm scenario

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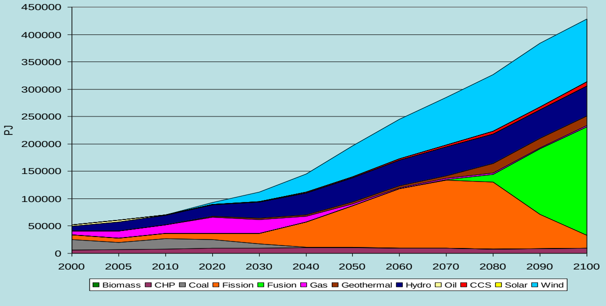
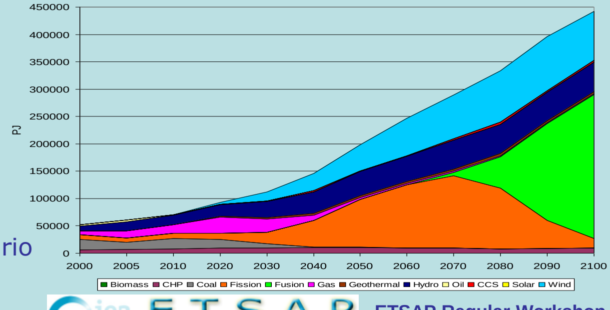
SENSITIVITY ANALYSIS- High Fusion Costs (+30%)



HFC scenario (+550ppm)

Power Generation



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- WInd

550 ppm scenario

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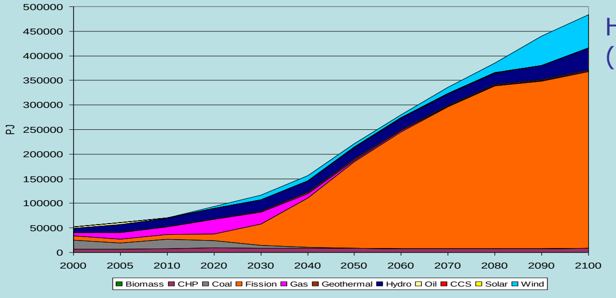
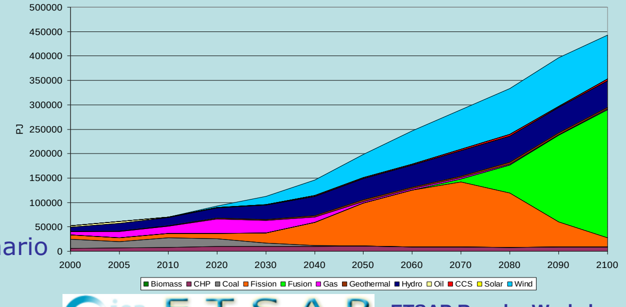
SENSITIVITY ANALYSIS- High Uranium Resources (x 10)



HUR scenario (+550ppm)

Power Generation



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- Solar
- WInd

550 ppm scenario

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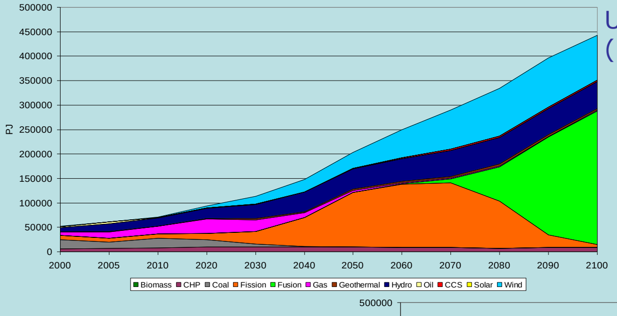
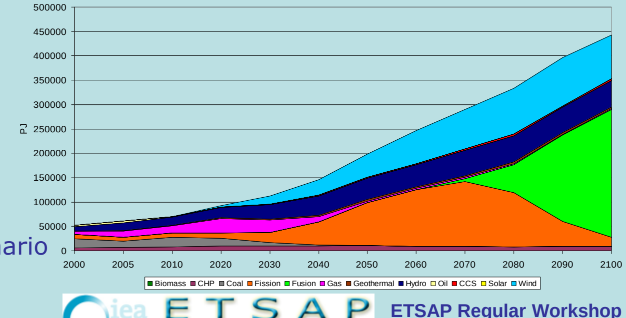
SENSITIVITY ANALYSIS- Uranium Low extraction Costs (-50%)



ULC scenario (+550ppm)

Power Generation



- Biomass
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550 ppm scenario

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POSSIBLE NEXT STEPS

- Re-aggregation of regions
- Re-calibration to a new base-year
- Introducing new TIMES options to the EFDA model
- Enhancement of model in nuclear power sector
- Review of technologies such as CCS, central solar power, road transport or storage technologies
- Review of resources such as uranium resources
- Review of demand drivers

CONCLUSIONS

- In the Base Case scenario, fusion does not enter the power system, while in the 550ppm one it is responsible of almost half of the global electricity production in 2100
- Also in primary energy, coal is displaced from a relevant position in 2100 by fusion and RES when limiting the CO_2 emissions
- Fusion penetration in the global power system is bigger and anticipates when the restrictions on the CO_2 emissions are stricter
- Fusion penetration is quite robust under cost increase
- In an utopian scenario with unlimited Uranium resource, fission technologies dominate the system from 2040
- Uranium costs reductions do not influence fusion development

Fusion has a chance in the low carbon energy systems

THANK YOU FOR YOUR ATTENTION!

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.

[3] EFDA. A Conceptual Study of Commercial Fusion Power Plants. Final Report (2005)