The long term potential of fusion power in Western Europe

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The authors analysed the potential of fusion power in Western Europe [1] [2]. The analysis is based on optimisations with the technology oriented MARKAL model.

With respect to methodological issues the following points are highlighted:

1. Technology assumptions are primarily based on detailed estimates, learning effects, and expert opinions included in studies of colleague institutes contributing to SERF and other studies.
2. The issue of discounting has been solved in the following way:
   - A relatively low discount rate of 2.5% per year governs the depletion of fossil fuel resources and cumulative CO_2 emissions.
   - A higher interest rate is considered appropriate for energy investment decisions, viz. from 5 to 8 and 10% per year for power generation.
3. Climate change is driven by the increased concentration levels of greenhouse gases. Stabilisation levels for CO_2 in the year 2100 (e.g. 450, 550, 650 and 750 ppm) can be translated into cumulative CO_2 emission budgets for Western Europe.

With respect to fossil fuel reserves the following assumptions have been made:

- Reserve/production ratio of oil: 130 years.
- Reserve/production ratio of gas: 190 years.
- Reserve/production ratio of coal: 220 years.
- Availability of fossil fuels to Western Europe: normally 10.5% of global resources.

The fossil fuel prices assumed in the two main scenarios are shown in Figure 1:

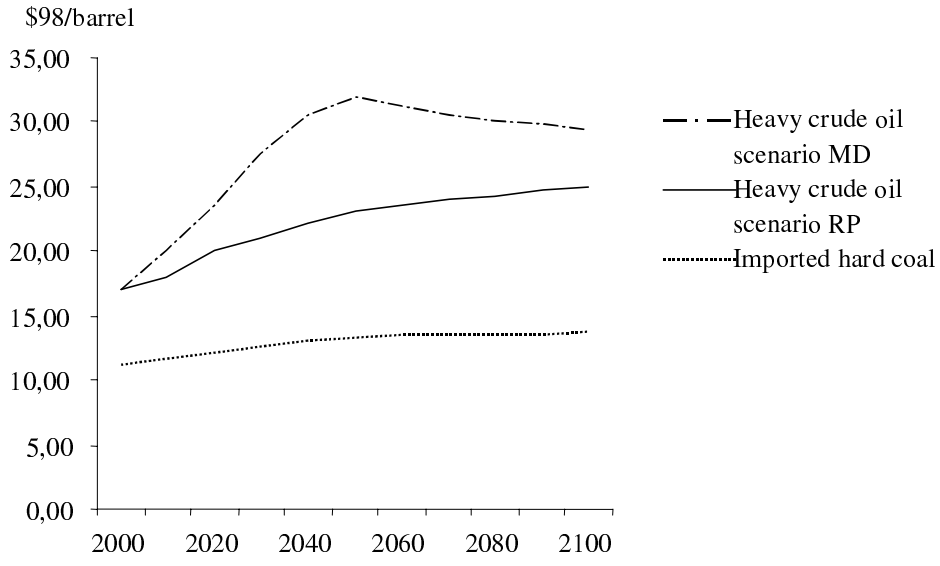

Figure 1 Heavy crude oil prices and coal price for two scenarios

Table 1 presents characteristic differences in key parameters of the two scenarios.

Table 1 Key differences between scenarios Rational Perspective (RP) and Market Drive (MD)

	Rational Perspective (RP)	Market Drive (MD)
Decision criteria	Uniform 5% discount rate for all energy decisions across all sectors	8% discount rate for power generation; higher discount rates for end use
Energy demand	Generally lower than in MD	Generally higher than in RP
Fossil fuel availability for Western Europe	10.5% of world's resources of coal, oil and natural gas	15% of world's resources of coal, oil and natural gas
Energy prices	Oil price increases slowly until 2100; $ 25/bbl in 2100	Oil price increases faster, peaking in 2050; $ 29.5/bbl in 2100
Fission power	Maximum capacity declining to 70% of current capacity and 40 GW in 2100	Maximum capacity declining to 80% of current capacity and 40 GW in 2100

Rational Perspective can be characterised as the ecologically driven scenario of the two. The process of global economic integration will lead to more collective public action in this scenario. International co-operation will be more efficient in order to deal with complex shared problems. Heavy polluters and energy intensive industries will decline in comparison to more environmentally friendly sectors like services. Strong penetration of new, more efficient demand and supply technologies is facilitated.

Results of scenario *Rational Perspective* are presented, more specifically of the base-case of the scenario without CO_2 constraint. Figure 2 shows the resulting power generation mix.

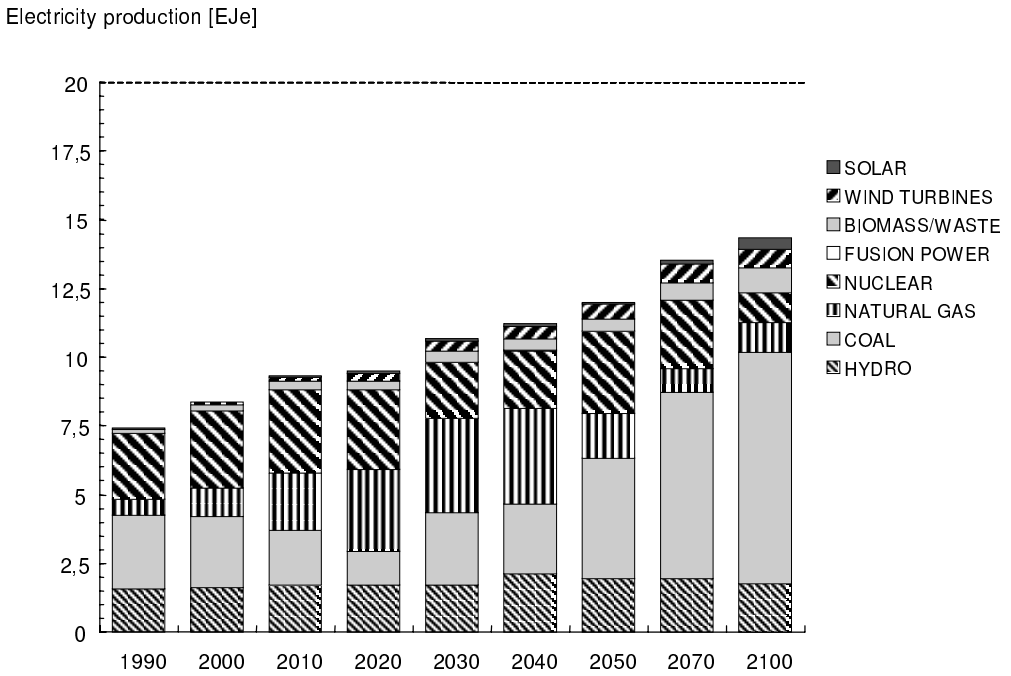

Figure 2 Power generation by source for scenario Rational Perspective without CO_2 constraint

Without CO_2 policies, fossil fuels are favoured for power generation. New renewables - wind, biomass, PV - show modest market shares. Fusion power cannot compete with alternative base-load power options in the absence of CO_2 policies.

The potential of fusion power has also been analysed under conditions of constrained CO_2 emission. Cumulative CO_2 emission budgets for Western Europe have been defined, corresponding to levels of global stabilisation of CO_2 from 450 to 650 ppm (Figure 3).

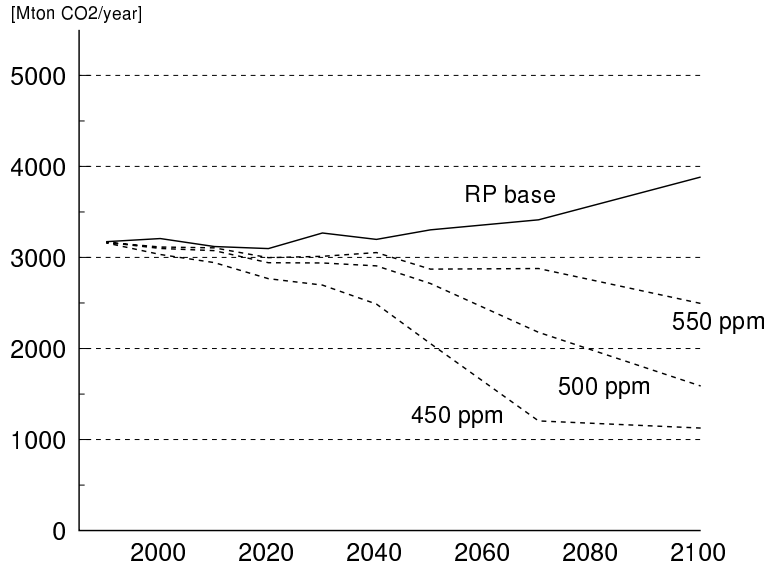

Figure 3 Western European CO_2 emissions, variants scenario Rational Perspective

Figure 4 shows the consequences of increasing CO_2 constraints for the power generation mix in the year 2100 in case of scenario Rational Perspective.

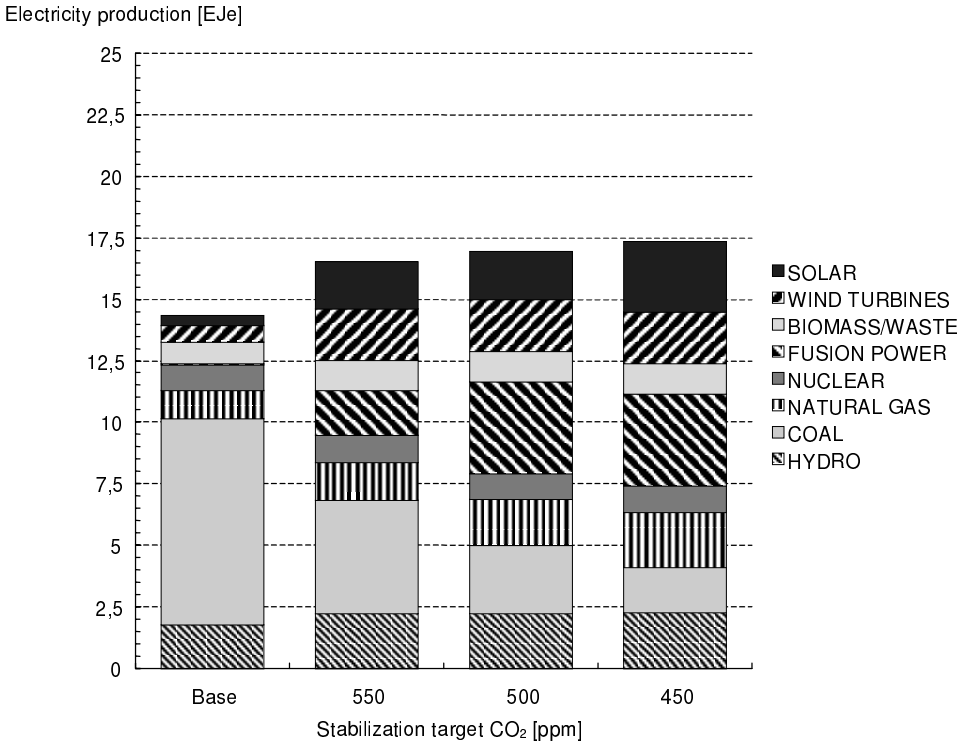

Figure 4 Power generation by source for the CO_2 variants of scenario Rational Perspective

In case of CO_2 constraints, fusion power becomes competitive at shadow prices ranging from about 30 to 70 ECU95/tCO_2

Finally, a sensitivity analysis has been done for the following cases:
- Scenario RP with discount rate 8% (the set of discount rates of scenario MD).
- Scenario RP with discount rate 10%.
- Scenario RP with phase-out of fission energy.
- Scenario RP with high availability of fossil fuels (15% of global resources, like MD).
- Scenario MD with discount rate 5% (like in scenario RP).
- Scenario MD with high investment cost of fusion power.
- Scenario MD with a high potential of renewable energy.
- Scenario MD with a high upper limit for fission energy (200 GW).

Table 2 shows fusion power capacity for the 'normal' scenario variants and for the sensitivity cases.

Table 2 *Installed fusion power, CO_2 variants and sensitivity cases, year 2100 [GW]*

Scenario	Case	650 ppm	550 ppm	500 ppm	450 ppm
RP		x [1]	78.4	157.5	157.5
RP	Disc. Rate 8%	x	102.3	157.5	157.5
RP	Disc. Rate 10%	x	140.3	157.5	157.5
RP	Phase out of fission	x	119.3	157.5	157.5
RP	High Fossil Fuel Avail.	x		119.3	157.5
MD		119.3	157.5	157.5	157.5
MD	Disc. Rate 5%	69.8	157.5	157.5	157.5
MD	High cost fusion	56.5	157.5	157.5	157.5
MD	High Potent. Renew.		83.0	119.3	157.5
MD	High Potential Fission	8.3	157.5	157.5	157.5

1 X means the unconstrained RP scenario is roughly comparable with the 650 ppm level.

Fusion power is generally maximised, if the CO_2 level should not exceed 500 ppm. At lower CO_2 levels - 550 ppm in case of scenario Rational Perspective, 650 ppm in case of scenario Market Drive - fusion power is also attractive. Another set of calculations concerns scenario variants without fusion power. Equal CO_2 stabilisation levels can be attained in that case, albeit at a higher cost.

References

[1] P. Lako, J.R. Ybema, A.J. Seebregts: *The long term potential of fusion power in Western Europe*. ECN--98-071, Petten, December 1998.

[2] P. Lako, A.J. Seebregts: *Characterisation of power generation options for the 21st century. Report on behalf of Macro task E1*. ECN-C--98-085. Petten, December 1998.