EUROPEAN ENVIRONMENTAL OUTLOOK 2005

Evaluation Workshop

Socio-Economic Assumptions, Energy and Climate Change

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27-28 April 2006

Energy, Transport and Climate Change Outlook: Issues Addressed

- Assessment of possible Greenhouse Gas Emission Reduction Pathways
- Greenhouse Gases Emissions projections and the underlying trends in the Energy Sector
- Explore possibilities for bringing about a transition to a low-energy low-emission system in cost-effective ways

Scenarios Developed

- Baseline Scenario
  - A continuation of current Environmental policies in the EU
    - with new policies only being introduced in developing countries
  - Modestly optimistic economic growth
  - European Population stable in the medium term – declines in the longer term
  - No climate policy becomes effective
  - Results at European Level based on LREM (Long Range Energy Modelling, European Commission, DG Energy & Transport)

- Climate Action Scenarios
  - Explore ways in which Europe can move towards long-term sustainable objectives especially with regard to climate change
  - Include policies and scenarios to reduce emissions of all six Kyoto gases for the relevant emitting sectors

Climate Action Scenarios

- **Low Carbon Energy Pathway (LCEP) Scenarios**
  - Carbon Prices alone determine the development of the Energy System
  - CO_2 price increase from 20€/tCO_2 in 2020 to 65 €/tCO_2 in 2030 (assumed to apply in the EU)
- Variants (in addition to the permit price):

(i) **'Renewables Expanded'**

Share of renewables in total energy consumption reaches 12% in 2010, 16% in 2020 and 20% in 2030

(ii) **'Nuclear Accelerated'**

New Evolutionary Nuclear technologies become available by 2010

(iii)**'Nuclear phase-out'**

Existing Nuclear plants are decommissioned at the end of their technical lifetime – no further investment in nuclear power occurs

Climate Change Targets

- Kyoto Protocol
  - Ratifying industrialised countries committed to an average emissions reduction of 2.8% by 2008-2012 (from 1990 levels)
- Global effort to limit global mean temperature increase to 2°C above pre-industrial levels

For the present analysis, the 2°C target translates into:

- Long term stabilisation of GHG concentrations at a level of 550 ppm CO_2-equivalent.
- EU emission reduction targets of 20 % below the 1990 level by 2020, 40 % by 2030 and 65 % by 2050.
  - Targets within the ranges mentioned by the EU Environment Council of March 2005

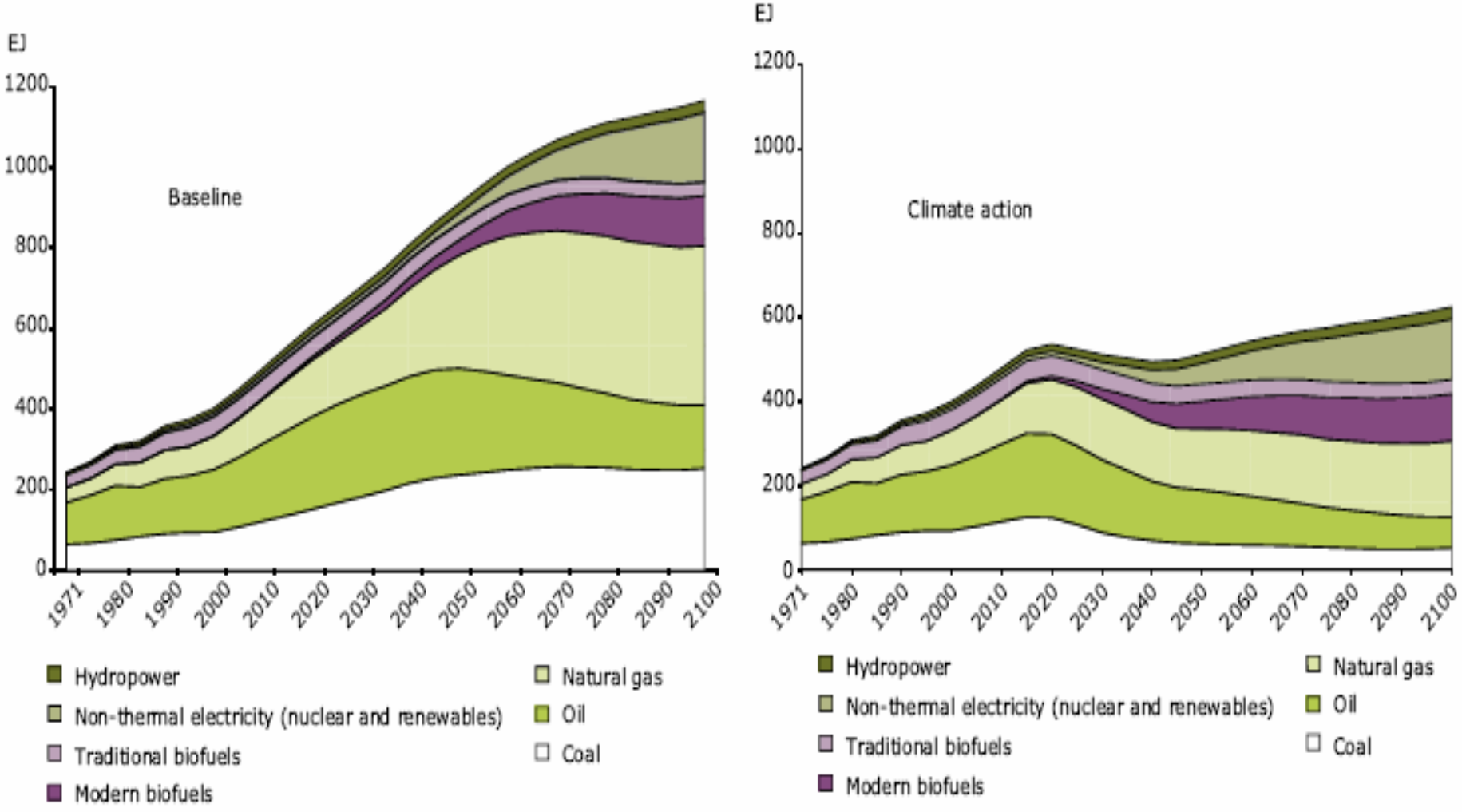
Baseline Scenario Results

- Total EU-25 GHG emissions: 2.3 % below 1990 levels by 2010. Emissions rise steadily after 2010, to 8% above 1990 levels by 2030.
- Global primary energy consumption increases by more than 2½ times by 2050 (and continues to rise to 2100).
- Fossil-fuel use grows even faster to 2050
  - It starts to stabilise thereafter as other fuel sources (most notably non-thermal electricity sources (solar/wind and nuclear power) grow rapidly.

Climate Action Scenario

- Global energy use increases slowly over the 2000–50 period, and is projected to be 40% lower than baseline levels in 2050
- Largest reductions for coal use (by 70% in 2050), followed by reductions in oil and natural gas use (reaching 50%)

Global Development in Energy Use



Note: Left baseline, right climate action scenario.

Source: IMAGE/TIMER model (EEA, 2005).

Climate Action Scenario Results:

- Achieving a global emission reduction of 15 % below the 1990 level by 2050 may need increases in the carbon permit price to 65€/t CO_2 by 2030.
- Energy related CO_2 emissions:11% below the 1990 level in 2030
  - Compared with 14 % above in the baseline scenario
- Low-cost emission reductions for nitrous oxide and methane emissions from industry, waste management and agriculture
  - However these options will have been almost fully exploited by 2030.
- In 2030, more than 70% of the CO_2 emission reductions are expected to be realised in the power generation sector
  - as a result of a shift to low or non-carbon fuels.

Climate Action Scenario Results:

- Decline in the use of Solid Fuels
- Rapid increase in the use of Natural Gas in the medium term
  - Its growth declines in the longer term as a result of higher natural gas import prices, and security of supply concerns.
- Renewable energy (mainly Wind Power and Biomass use) sees the largest increase
  - 42% higher than baseline (340% higher than 1990)
- The additional annual costs of the climate action scenario (compared with the baseline) reach 100 bn€ by 2030
  - The industrial sector facing the largest burden (on average about 1.6 % of the value added of the sector)
  - Relatively small additional costs for households (about 110–120€ per household by 2030)
    - compared with 1900€/household increase in energy costs in the baseline (EU-15) and 3400€ (EU-10) by 2030

Variant Scenario Results

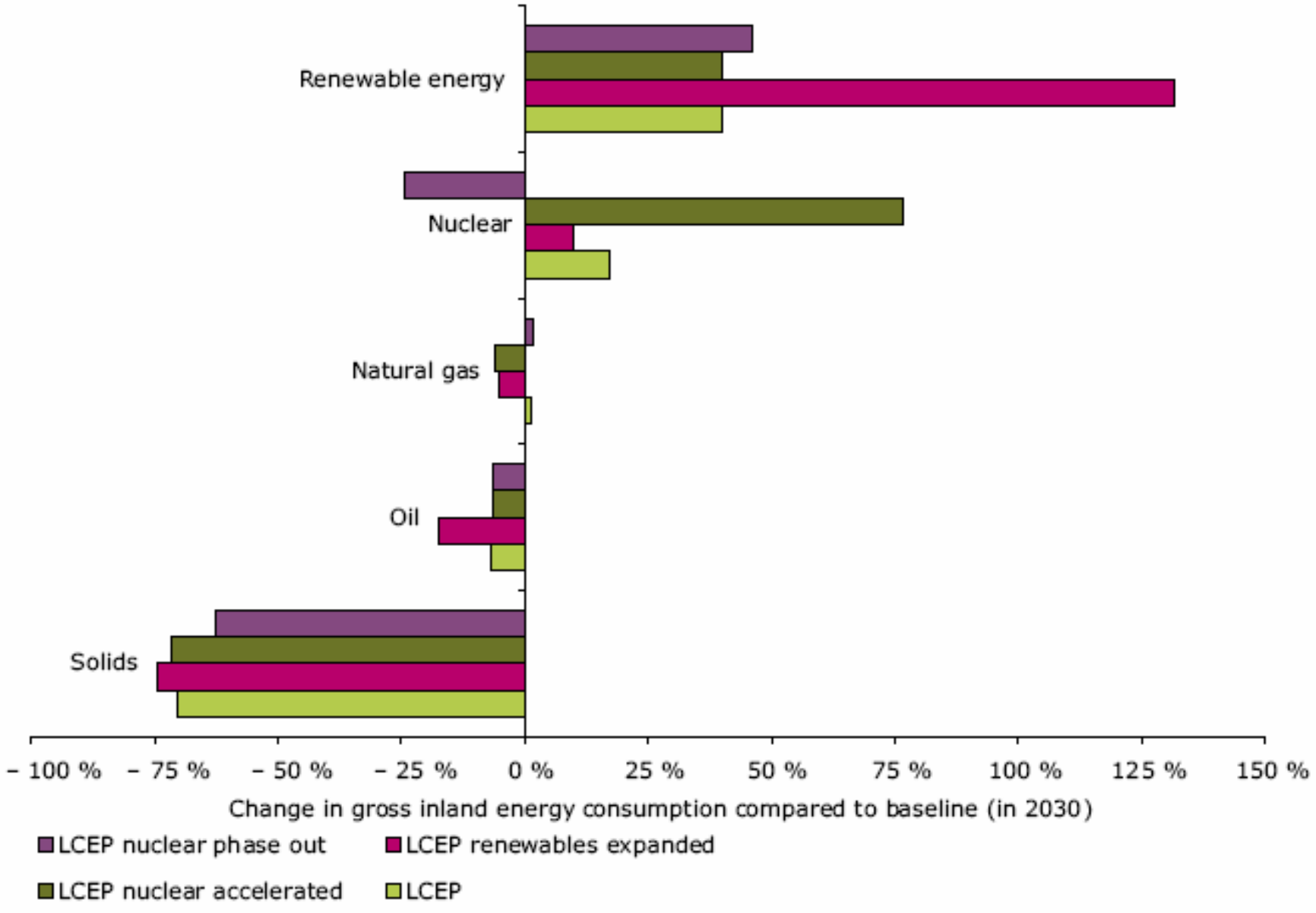
- On a basis of a carbon permit price of 65€/t CO_2 EU could reduce its emissions in 2030 (relative to 1990) by:
  - 21% in the Renewables Expanded scenario
  - 14% in the Nuclear accelerated variant
  - 8.4% in the 'Nuclear Phase-Out' variant

√ International emissions trading providing the remaining reductions to reach the 40% target

- Considerable reductions in CO_2 emissions from industry, services and household sectors
  - Arising from fuel switch in industry and efficiency improvements in heating, electrical appliances and lighting.

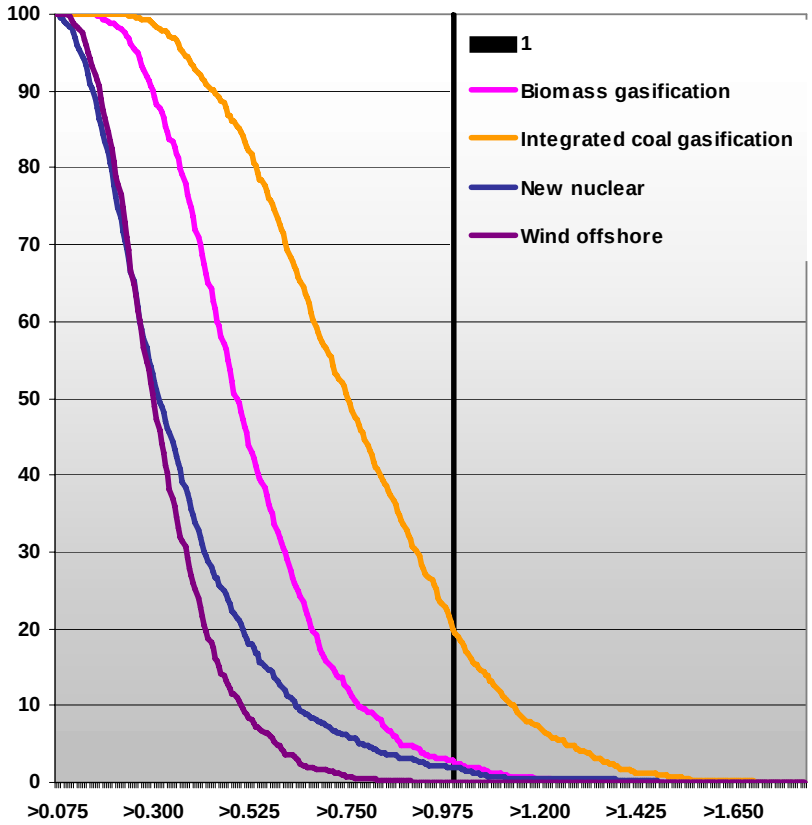
- CO_2 emissions from transport continue to grow in all scenario variants (to 25–46% above the 1990 level by 2030)
  - because of the steady increase in passenger and freight demand

Changes in the Fuel Mix of EU-25 gross inland energy consumption relative to Baseline in 2030



Power generation sector – production cost in 2050 (Europe)

Costs are relative to Gas Turbine Combined Cycle



Probability of high effective carbon values mean high risks for fossil technologies

	Probability (%) of less than 1 in:	
	2025	2050
Biomass Gasification	60.8	97.2
Integrated Coal Gasification	54.6	80.5
New Nuclear	3.1	98.1
Wind Offshore	97.7	100

Technology share in power generation

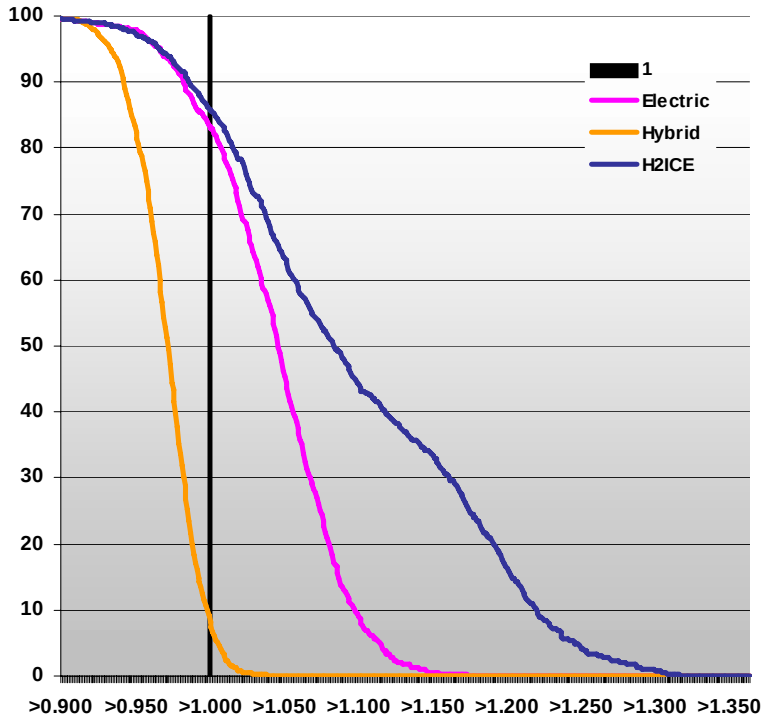
Share in electricity production in 2030 (Europe)											
	Hydro	Wind	Solar	Biomass Gasification	Biomass Thermal	Renewable (excl. hydro)	Nuclear	Carbon Capture and Seq.	Clean Coal	Super critical coal	Gas turbine combined cycle
Mean	15.08	10.78	0.36	2.19	3.43	16.76	20.87	3.17	6.95	8.98	15.07
Median	14.27	9.56	0.19	1.72	2.97	16.17	18.23	2.25	5.28	6.67	14.00
St.dev	3.91	6.10	0.50	1.68	1.65	6.33	7.19	2.89	5.38	7.34	4.89
Lower 5%	10.75	2.99	0.05	0.48	1.85	7.52	13.57	0.35	1.30	1.83	9.23
Upper 5%	22.50	22.56	1.26	5.47	6.76	28.88	35.41	9.08	18.24	24.11	24.34
Share in 2000	17.96	0.81	0.00	0.13	2.00	2.93	32.01	0.00	0.00	0.00	8.98
Probability to exceed 2000	15.6	100	100	99.9	90.0	100	9.0	100	100	100	96.2

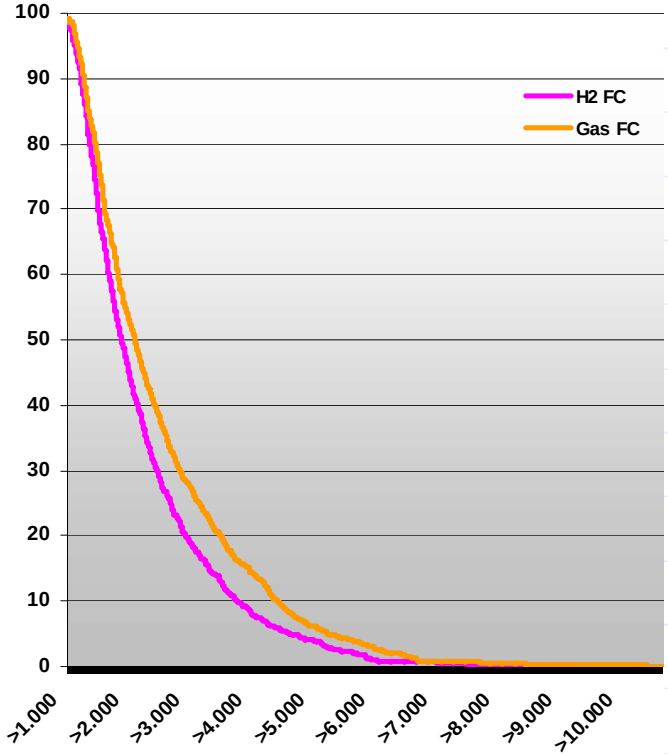
Share in electricity production in 2050 (Europe)											
	Hydro	Wind	Solar	Biomass Gasification	Biomass Thermal	Renewable (excl. hydro)	Nuclear	Carbon Capture and Seq.	Clean Coal	Super critical coal	Gas turbine combined cycle
Mean	13.57	14.31	4.64	2.83	3.12	24.90	21.92	7.17	7.34	9.27	7.97
Median	12.43	13.30	3.56	2.30	2.70	24.15	18.96	5.85	5.72	7.14	7.84
St.dev	4.94	7.50	3.89	2.09	1.56	8.41	10.46	5.42	5.91	7.73	1.61
Lower 5%	8.35	4.32	0.70	0.69	1.63	12.18	10.18	0.96	1.06	1.66	5.61
Upper 5%	22.98	28.51	13.04	6.75	6.00	39.15	42.60	17.51	20.39	25.84	10.61
Share in 2000	17.96	0.81	0.00	0.13	2.00	2.93	32.01	0.00	0.00	0.00	8.98
Probability to exceed 2000	13.2	100	100	100	80.0	100	16.8	100	100	100	24.0

- **Hydro potential in Europe is nearly exhausted: The probability of a share higher in 2050 than in 2030 is 11.6 %**
- **The probability that the share of wind technologies will be the highest among the shares of the other renewable technologies in 2050 is 74.9 %**
- **The probability that the wind offshore production will be higher than wind onshore in 2050 is 29.5 % (in 2030 it is only 2.6 %)**
- **Gas turbine combined cycle loses share in the longer term in favour of the other power generation technologies**
- **The probability that the share of clean coal is lower in 2050 than in 2030 is around 47 %**
- **The probability that the share of CO2 capture and storage technologies is lower in 2050 than in 2030 is 11.5 %**

Transport sector - cost per km for passenger cars in 2050 (Europe)

Costs relative to the otto engine car cost/km





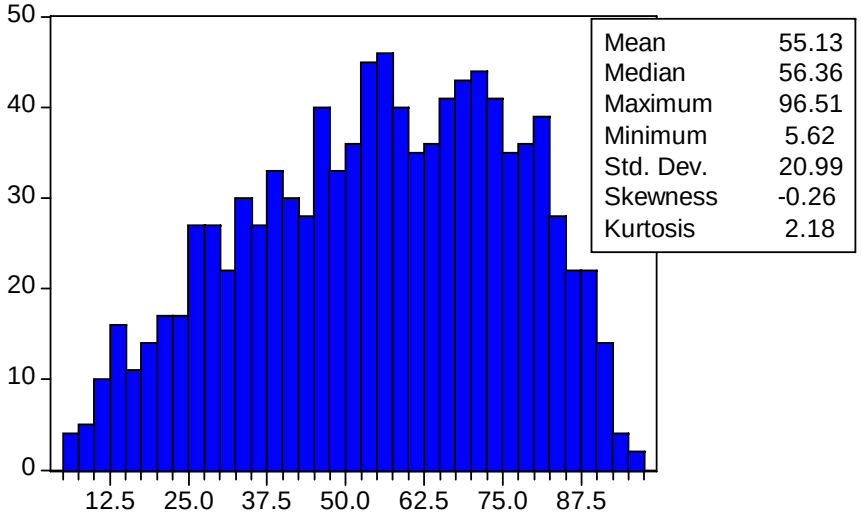
Probability of less than 1

- **Electric: 18.0 %**
- **Hybrid: 92.0 %**
- **H2ICE: 14.7 %**

Probability of less than 2

- **Gas Fuel Cell: 47.0 %**
- **H2 Fuel Cell: 55.0 %**

Share of non-conv. vehicles in total stock % in 2050 (World)



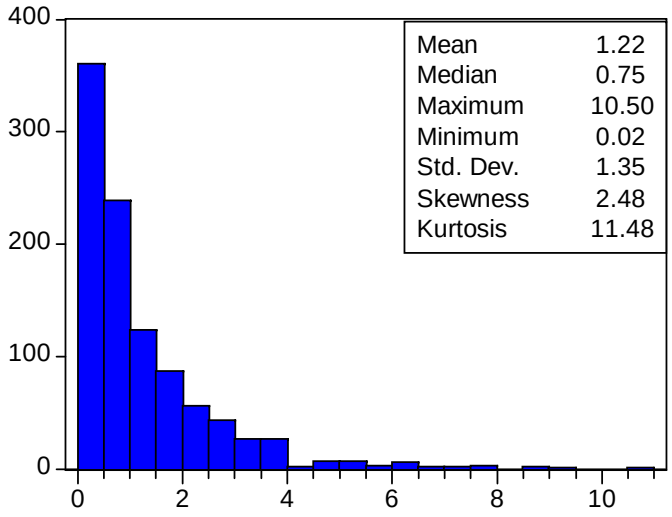
Probability of a share of non conventional to conventional vehicles of:

- more than 50% is 61%
- less than 15% is 3.5%
- more than 85% is 6.3%

Hydrogen sector

Share in hydrogen production in 2050 - World					
	Fossil fuels	**Renewable**	**Nuclear**	**Electrolysis**	**Carbon Capture and Seq.**
Mean	27.88	32.99	20.64	9.45	9.04
Median	20.44	25.07	9.61	2.27	2.88
St.dev	25.30	29.29	24.90	16.05	14.04
Lower 5%	0.40	0.65	0.12	0.03	0.05
Upper 5%	78.68	90.63	77.42	49.89	40.95

Share of hydrogen in final consumption %



Probability of more than 5% share of H_2 in total final energy demand: 2%

The share of technologies in hydrogen production is affected by:

- **Carbon value (fossil fuel technologies)**
- **Breakthroughs on nuclear technologies**
- **More decentralized H_2 generation structure (renewable technologies)**

Correlation matrix of a subset of PROMETHEUS variables

	World GDP av. annual growth rate	Av. oil int. price	Av. gas int. price	Av. carbon value	Cum. CO2 emiss.	Elec. final cons. in 2050	Other final cons. in 2050	Transp. activity in 2050	REN share in elec. prod. in 2050	H2 dem. in 2050	Non conv. Veh. share in 2050	Non conv. oil prod. in 2050	Cum. R&D in 2050	Biomass gassif. capital cost in 2050	Integr. Coal Gasif. capital cost in 2050	De-central. PV capital cost in 2050
Average oil int. price	**0.57**															
Average gas int. price	**0.46**	**0.75**														
Average effective carbon value	0.07	0.03	0.04													
Cumulative CO2 emissions	**0.54**	**0.42**	0.28	-0.12												
Electricity final consumption in 2050	**0.76**	**0.46**	**0.41**	0.00	**0.57**											
Other final consumption in 2050	**0.60**	**0.45**	0.34	-0.23	**0.45**	**0.42**										
Transport activity in 2050	**0.59**	0.31	0.22	-0.15	0.38	**0.46**	**0.41**									
Renewable share in elec. prod in 2050	0.07	0.11	0.20	0.14	-0.03	0.01	0.04	0.00								
Hydrogen demand in 2050	0.29	0.18	0.26	0.06	0.15	0.25	0.23	0.20	0.04							
Non conventional vehicles share in 2050	0.17	-0.10	0.01	-0.01	0.06	0.18	0.12	0.21	-0.04	0.29						
Non conventional oil production in 2050	**0.44**	**0.77**	**0.51**	0.02	0.32	0.35	0.35	0.21	0.02	0.12	-0.12					
Cumulative R&D expenditure in 2050	**0.74**	**0.83**	**0.80**	0.17	0.35	**0.58**	**0.47**	0.39	0.18	0.28	0.04	**0.62**				
Biomass gassification capital cost in 2050	**-0.73**	**-0.83**	**-0.83**	-0.17	-0.35	**-0.59**	**-0.45**	-0.38	-0.20	-0.28	0.00	**-0.60**	**-0.96**			
Integrated Coal Gasificiation capital cost in 2050	**-0.65**	**-0.67**	**-0.64**	-0.03	**-0.45**	**-0.56**	-0.39	-0.36	-0.06	-0.26	-0.05	**-0.48**	**-0.74**	**0.78**		
Decentralised PV capital cost in 2050	**-0.46**	**-0.49**	**-0.54**	-0.11	-0.23	-0.35	-0.30	-0.26	-0.18	-0.19	-0.02	-0.32	**-0.59**	**0.63**	**0.49**	
New nuclear capital cost in 2050	**-0.40**	-0.34	-0.37	-0.07	-0.17	-0.39	-0.22	-0.21	0.10	-0.11	-0.06	-0.26	**-0.44**	**0.46**	0.31	0.30

Bold figures mark correlations greater than 0.4;red highlights significant negative correlations

PROMETHEUS results suggest that uncertainty concerning the future energy system lies mostly along an axis dominated by economic activity

- High growth is associated with:
  - Fast fossil fuel resource depletion and high prices
  - High emissions
  - High R&D investments
  - Extensive innovation (both from learning by experience and research)
  - Low capital costs
  - Faster transformation of the energy system
- Uncertainty driven by demand in a resource constrained world where both demand and supply are relatively price inelastic.

General remarks on Scenarios

- Baseline and SEP scenarios
  - Have quickly become a sort of Reference
    - Consistent
    - Transparent
    - "Robust" – soundly based on detailed analysis
  - Some Problems on the appropriate level of detail
  - Problems with Timeliness
    - Rapid evolution of key parameters and concerns
    - Solution (?): Regularise and constantly update?

General remarks on Variants

- Useful in:
  - Exploring specific issues
  - Establishing the robustness of key conclusions
- A possible proliferation could lead to confusion

Uncertainty Analysis

- Often Absent in Prospective analysis
  - This Absence can lead to major misconceptions
  - EEO 2005 contains some analysis of this kind
- Important both on Analytic and Strategic Grounds
  - Major drawbacks: Complexity and Unfamiliarity of Concepts
  - Emerging Tools
    - Could future EEOs support such analysis and at the same time “educate” ?