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Role and Potential of Renewable Energy and Energy Efficiency for Global Energy Supply

Summary

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Role of renewable energy and energy efficiency in global energy scenarios

A broad range of different global energy scenarios confirms that ***the exploitation of energy efficiency potentials and the use of renewable energies play a key role in reaching global CO_2 reduction targets.***

In scenarios aiming at the stabilisation of greenhouse gas concentration at 450 ppm CO_2 equivalent, ***the contribution of renewables to global primary energy supply reaches up to 56% (Greenpeace/EREC, Energy [R]evolution) in 2050.*** By 2030, renewables are expected to reach between 23% (IEA World Energy Outlook 2008, 450 Policy Scenario) and 31% (Greenpeace/EREC, Energy [R]evolution).

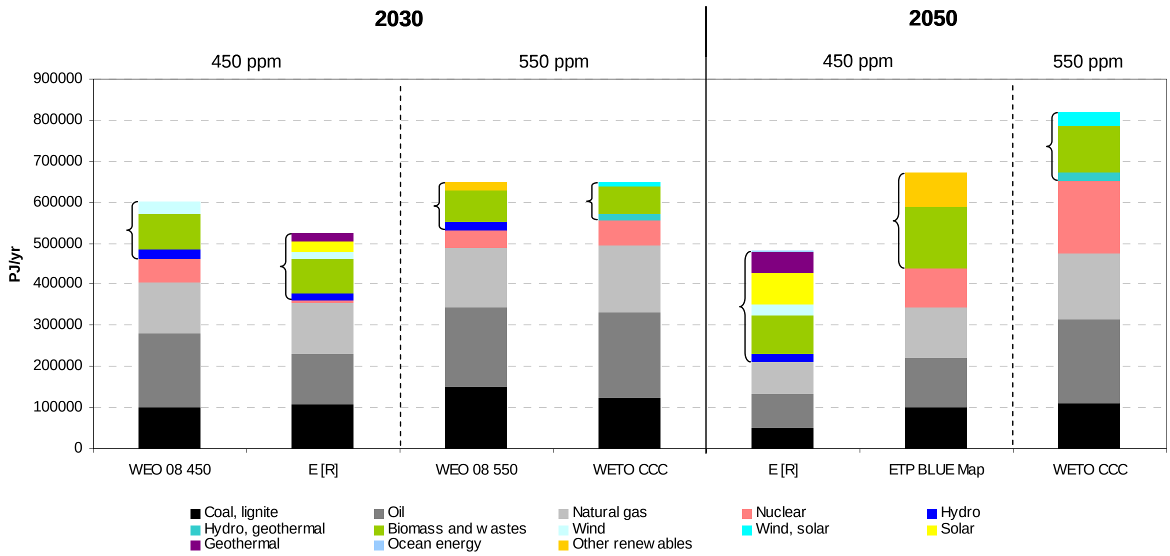

Figure 1: Contribution of renewable energies to primary energy supply in different scenarios. Segmentation follows time and climate targets.

Differences in the share of renewables across scenarios are partly due to different assumptions on the potentials for increasing energy efficiency. Compared to other scenarios, the more ambitious reduction of energy demand in the Greenpeace/EREC Energy [R]evolution scenario facilitates higher shares of renewables in energy consumption. However, until 2050 final energy demand per unit of GDP decreases in all scenario studies.

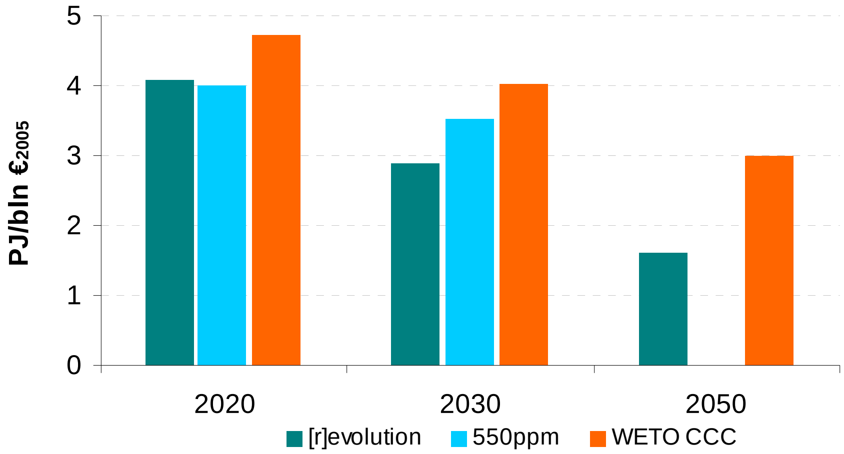

Figure 2: Development of global energy intensity in different scenarios

In contrast to the Greenpeace/EREC Energy [R]evolution scenario, in the IEA scenarios, nuclear and fossil technologies with carbon capture and storage (CCS) are also considered to be essential elements for achieving the climate protection targets. In particular the use of CCS in the IEA WEO 450 Policy Scenario leads to high CO_2 abatement costs, as CCS is not expected to gain economic competitiveness before 2030. ***It remains unclear what constraints the market uptake of more cost effective renewable options in the IEA scenarios.***

While all scenario studies analysed provide a wealth of detailed information on various technical and economic issues, ***there is a general lack of reporting key assumptions in a comprehensive and transparent way***, which sometimes makes comparison across studies difficult. All studies analysed are particularly weak in providing data on the heating sector, which in spite of its large contribution to fuel consumption and CO_2 emissions in general is treated as a second priority only. A more transparent documentation of basic assumptions and constraints is desirable for any future scenario work.

Global potentials of renewable energy sources

The overall technical potential for all renewable energy technologies is high, when compared to current and future energy needs as projected in the IEA's World Energy Outlook 2008. ***Current global final energy consumption*** (338.5 EJ/yr according to IEA energy statistics for 2006) ***is accounting for less than 5% of the overall projected technical renewable energy potential.*** Consequently, availability of technical renewable energy potential is not a constraint for future development of renewable energy sources. The technical potential is a somewhat theoretical figure, however, and should not be confused with the economic or deployment potential.

The largest technical electricity generation potential on a global scale is seen for the solar technologies concentrating solar thermal power plants (CSP) and photovoltaics (PV), followed by wind onshore and ocean energy. The global technical potential for direct thermal use of solar and geothermal energy can only be roughly estimated, but exceeds global low temperature demand by several times.

The potential for CSP and PV electricity generation is particularly large in Africa. Wind onshore potentials are high in North America, while Latin America has abundant biomass resources.

Table 1: Regional technical renewable energy potential for 2050

	Technical Potential EJ/yr electric power							**EJ/yr heat**		**EJ/yr primary**	
	Solar PV	Solar CSP	Wind Onshore	Wind Offshore	Hydro power	Ocean	Geo-thermal	Geo-thermal	Solar	Biomass energy crops	Biomass Residues
Africa	717.1	4348.3	27.7	1.6	6.8	18.0	4.1	212.3	10.3	0.0	13.8
Middle East	127.2	1153.0	4.9	0.5	1.0	7.6	0.7	37.7	1.8	0.0	1.1
OECD Pacific	225.3	1513.0	53.5	3.4	1.2	29.7	4.2	68.7	2.8	3.2	6.2
Rest of Asia	136.5	9.2	8.5	10.0	6.5	149.7	5.8	109.6	21.1	0.0	8.0
Latin America	118.2	298.8	36.2	10.6	9.0	44.0	4.7	158.7	21.1	47.0	12.6
Trans. Economies	116.0	203.8	65.2	9.4	4.8	0.1	5.6	136.7	5.8	19.0	5.3
North America	84.0	347.2	159.2	6.9	6.0	45.7	6.4	148.0	23.8	19.0	17.6
OECD Europe	33.2	4.1	18.5	12.8	7.4	25.0	1.8	51.3	23.3	8.4	7.5
China	97.8	59.8	4.0	1.5	5.4	7.4	4.6	87.2	17.4	0.0	7.7
India	33.5	106.3	1.4	0.8	1.9	4.1	1.6	29.9	6.0	0.0	7.8
World	1688.8	8043.5	379.0	57.0	50.0	331.2	44.8	1040.0	123.0	96.5	87.6

Costs of renewable energy technologies

In general the cost estimates for renewable electricity generation technologies and even long term cost projections across the key studies are in reasonable agreement. For well known technologies like PV or wind the differences in future cost assumptions are quite small. They are larger for technologies in an early development stage, for which there is not yet an established lead technology (like wave energy). Differences between cost estimates can also be large when site specific conditions influence investment costs, like in the case of hydropower or geothermal energy. Furthermore, the variation in cost data is large when a variety of different technical concepts and different applications exists, like in the case of biomass use.

For most renewable energy technologies cost estimates in IEA-ETP are, in general, towards the lower range of cost estimates, although the share of renewables in the IEA scenarios in general is smaller than in the other scenario studies. Costs for renewable energy technologies in the Greenpeace/EREC scenario, which is a dedicated ‘renewables’ scenario, are in most cases higher than the IEA estimates.

Results show that for all renewable technologies except hydro it is expected that a significant reduction in electricity generation costs can be realised over the next twenty years. Taking into account an expected increase in fossil fuel prices and CO_2 emission costs, ***it is most likely that by 2030 most of the renewable electricity generation technologies will be competitive against electricity generation from fossil fuels.***

Cost data on renewable heating and cooling technologies are quite poor in all the scenario studies analysed. As far as data are available, and taking into account the large uncertainties which partly are due to differences in plant size and in the type of application, there is a reasonable agreement across scenarios on cost data for solar collectors and biomass heating systems. There is however a significant difference in assumptions on costs for heat pumps using shallow geothermal resources.

Table 2: Future cost projections for renewable electricity generation technologies

			~ 2010		2020 – 2030		~ 2050	
			range	'indicative estimate'	range	'indicative estimate'	range	'indicative estimate'
Photovoltaics	Invest. costs	€/kW	2800 - 4420	3000	1000 - 1530	1050	860 - 900	880
	O&M costs	€/(kW.a)		30		10		9
Concentrating solar thermal power plants	Invest. costs	€/kW	3600 - 5050	5050	3300 - 3700	3500	2770 - 3440	3400
	O&M costs	€/(kW.a)		200		140		135
Wind								
- wind onshore	Invest. costs	€/kW	970 - 1100	1050	850 - 900	880	800 - 900	870
	O&M costs	€/(kW.a)		40		35		30
- wind offshore	Invest. costs	€/kW	1800 - 3000	2770	1100 - 1800	1700	1000 - 1500	1400
	O&M costs	€/(kW.a)		120		75		40
Biomass								
- biomass power plant	Invest. costs	€/kW	2000 - 2600	2200	1500 - 2300	2000	1400 - 2300	1900
	O&M costs	€/(kW.a)		130		120		110
- biomass CHP	Invest. costs	€/kW	1750 - 4600	3900	1650 - 3100	2600	1600 - 2400	2000
	O&M costs	€/(kW.a)						
Geothermal (EGS)	Invest. costs	€/kW	4000 - 15000	12000	3200 - 8050	6350	2400 - 8000	5050
	O&M costs	€/(kW.a)		450		235		190

			~ 2010		2020 – 2030		~ 2050	
			range	‘indicative estimate’	range	range	‘indicative estimate’	range
Hydro								
-large hydro	Invest. costs	€/kW	800 - 4400	2000	800 - 4350	2200	800 - 4100	2500
	O&M costs	€/(kW.a)		80		90		95
-small hydro	Invest. costs	€/kW	2000 - 5600	3500	1800 - 5200	4000	1600 - 4800	4000
	O&M costs	€/(kW.a)		180		200		200
Ocean energy								
- tidal barrage	Invest. costs	€/kW	1600 - 3200	2400	1400 - 2800	2100	1200 - 2400	1800
	O&M costs	€/(kW.a)		95		85		70
- tidal current	Invest. costs	€/kW	5600 - 8000	6800	4000 - 6400	5200	2800 - 4800	3800
	O&M costs	€/(kW.a)		270		210		150
- wave	Invest. costs	€/kW	3000 - 12000	7000	1500 - 4000	2000	1200 - 3200	1300
	O&M costs	€/(kW.a)		280		80		50

Table 3: Future projections of investment costs for renewable heating technologies

		2005		2020 – 2030		~ 2050	
		range	'indicative estimate'	Range	'indicative estimate'	range	'indicative estimate'
Solar collectors							
- small scale systems	€/kW	240 – 800	630		250		230
- large scale systems (for heating networks)	€/kW	240 - 800	300		220		190
Geothermal							
- deep geothermal	€/kW	50 - 720	500	55 – 600	500		500
- shallow geothermal/heat pump	€/kW	500 - 1500	1300	170 – 1220	1100		1050
Biomass							
- small-scale heating system	€/kW	380 - 1800	790		700		650
- heating plant	€/kW		650		480		450

Global potentials of energy efficiency

In order to estimate technical potentials for energy efficiency improvement a reference scenario has been defined on the basis of the reference scenario developed for Greenpeace/EREC's Energy Energy [R]evolution] scenario (2007). On a business-as-usual trajectory worldwide final energy demand is expected to grow by 95% from 290 EJ in 2005 to 570 EJ in 2050. By exploiting the derived technical potential for energy efficiency improvement in that period the increase can be limited to 8%, respectively, total final energy demand to 317 EJ in 2050. ***The global technical potential for energy efficiency improvement in the energy demand sectors corresponds to 2.4% per year*** and ranges from 2.1% to 2.6% per year depending on the region. In sum, the projected efficiency measures constitute a technical potential of 253 EJ savings in final energy demand until 2050. ***For the transformation sector, the energy efficiency improvement potential corresponds to 1.4% per year*** and ranges from 0.9% to 2.3% per year.

The global technical potential for savings in primary energy by implementation of the projected measures accounts for 475 EJ until 2050. ***Primary energy supply can be limited to 392 EJ in 2050. This is 10% below primary energy supply in 2005 (440 EJ)*** and 55% lower than the primary energy supply in 2050 in the case of business-as-usual development.

Table 4: Summary of technical potentials per sector in energy efficiency improvement per year for period 2010-2050

Region	Buildings and agriculture	Industry	Transport	**Total energy demand sectors**	Transformation sector
OECD Europe	2.6%	2.2%	2.9%	2.2%	1.1%
OECD North America	2.5%	2.3%	3.0%	2.6%	0.9%
OECD Pacific	2.0%	2.2%	2.8%	2.5%	1.0%
Transition economies	2.0%	2.3%	2.8%	2.2%	2.3%
China	2.0%	2.6%	2.4%	2.4%	1.5%
India	2.2%	2.6%	2.4%	2.4%	1.6%
Rest of developing Asia	2.0%	2.4%	2.6%	2.3%	0.9%
Middle East	2.2%	2.8%	2.9%	2.6%	1.9%
Latin America	2.2%	2.5%	2.9%	2.5%	1.7%
Africa	1.8%	2.3%	2.8%	2.1%	1.7%
World	**2.2%**	**2.4%**	**2.8%**	**2.4%**	**1.4%**

Costs and bounds of energy efficiency

To implement the global technical potential, annual costs equivalent to 0.5% of GDP in 2050 have been estimated, based on case studies for OECD Europe and China. It was found that ***there is a large potential for cost-effective measures.***

Cost estimates for efficiency measures are very sensitive to fuel price assumptions. They can change from positive to negative costs just by higher fuel price assumptions. Also the applied discount rate influences costs significantly as well as assumptions regarding incremental investment costs of energy efficiency measures and estimated fuel savings. Further research is therefore needed to estimate global and regional costs of energy efficiency measures.

There are however a number of market failures and barriers that inhibit the uptake of energy efficiency measures. These are e.g. insufficient and inaccurate information, capital market barriers, low energy costs and low price elasticity. ***Policies aimed at removing market barriers are important to stimulate energy efficiency improvement.***

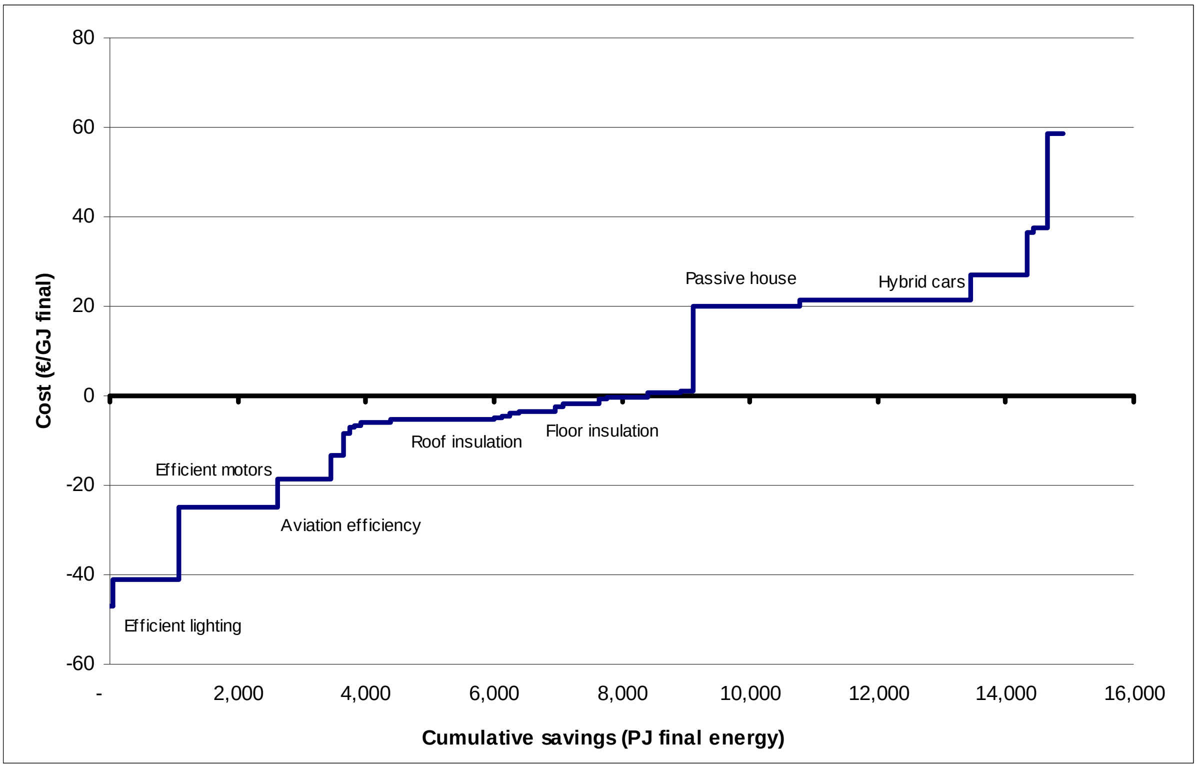

Figure 3: Cost curve for energy savings in OECD Europe

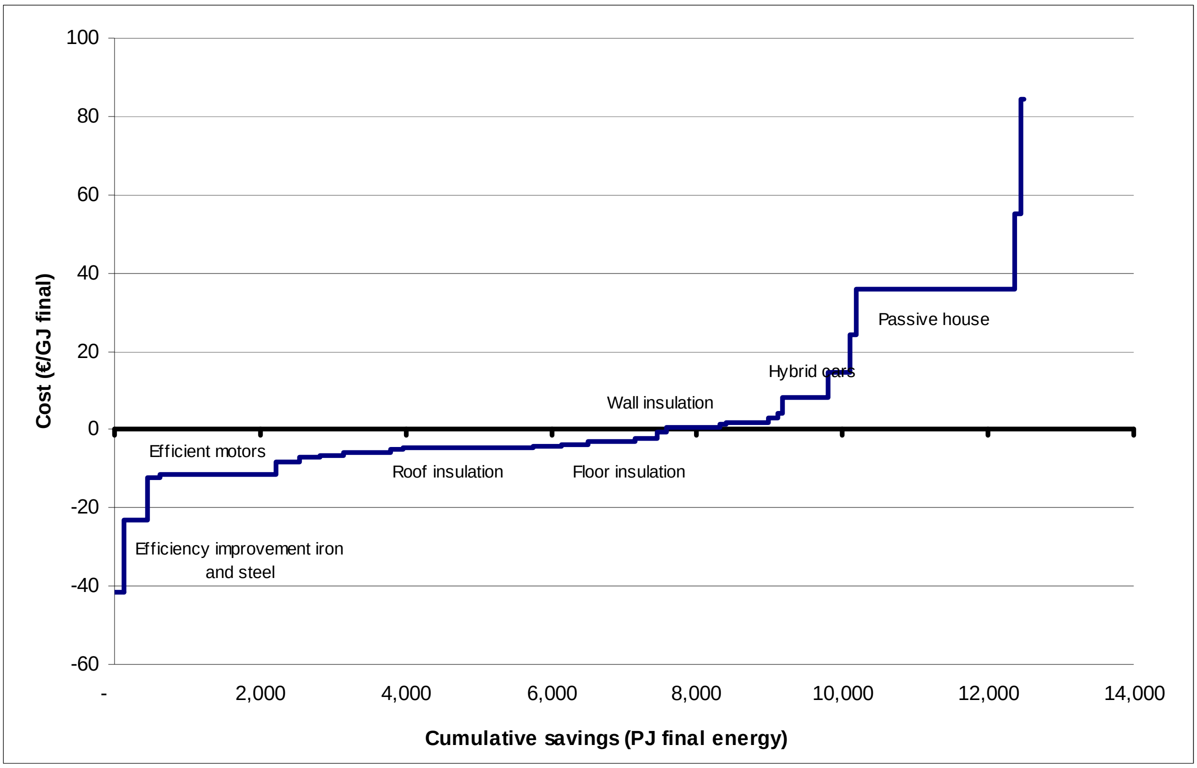

Figure 4: Cost curve for energy savings in China

Energy consumption and behavioural changes

The results of the analysis on behavioural changes being integrated in energy scenarios show that behavioural dimensions are not sufficiently included. Some scenarios completely omit this dimension, other scenarios indicate that explicit behavioural changes play a role, but the scenario modellers do not make explicit behaviour a guiding principle in their modelling. Two explanations for these approaches (or omittances) are possible: 1) explicit behavioural changes (of individual actors and groups) are not considered to play a role in future energy systems 2) explicit behaviour is considered to be too complex to be modelled in energy scenarios.

It should be discussed whether behavioural dimensions can be explicitly integrated into the existing architecture and logic of scenarios at all, or whether the scenario structures themselves need to be changed. ***It is still an open question to what extent explicit behavioural dimensions can be quantified at all*** or to what extent they have to remain a parameter that can only be analysed qualitatively.

Revealed major research challenges are twofold: To find ways to integrate behavioural changes into current scenario structures as well as to develop different scenario approaches to focus on behavioural changes as a major parameter.

The integration of behavioural changes into current scenario structures remains a great challenge that has not yet been addressed in a satisfactory way. As a first approximation of integrating some elements of behavioural change into scenario modelling, the focus should be put on the following aspects:

- References to individual actors and consideration and integration of social and cultural relations (context of “Lebenswelt”).

- A stronger reflection of the normative orientations of the scenarios themselves should be combined with the development of means to methodically deal with norms.

Behavioural changes could be integrated better into more open and transparent scenario models that allow detailed modifications of assumptions. Typical bottom-up models could principally be used for this: they allow setting assumptions for each sector and each technology separately, which helps to make the modelling and its results as transparent as possible.

Resumé

The report’s results emphasise that there still is a considerable unexploited potential for renewable energy, energy efficiency as well as for behavioural changes to reduce future global energy-related CO_2 emissions. The overall technical and behavioural potentials for renewable energy technologies and energy efficiency improvements are significant. Further development is needed for their exploitation, in particular for overcoming economical, infrastructural and political constraints.