The blessings of energy efficiency in an enhanced EU sustainability scenario

Stefan Lechtenböhmer
Wuppertal Institute for Climate, Environment, Energy
Germany
stefan.lechtenboehmer@wupperinst.org

Adriaan Perrels
Government Institute for Economic Research VATT
Finland
adriaan.perrels@vatt.fi

Maike Bunse
Wuppertal Institute for Climate, Environment, Energy
Germany
maike.bunse@wupperinst.org

Anja Scholten
University of Würzburg, Geographical Institute
Germany
Anja.Scholten@uni-wuerzburg.de

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Abstract
Although the anticipated 'end of cheap oil' has boosted the interest in energy efficiency as a cornerstone of energy and climate strategies, it is usually taken into account on the basis of rather narrowly defined cost-benefit considerations. As a consequence, substantial ancillary benefits are usually barely considered.

In a recent study for the European Parliament (EP), the authors assessed two enhanced climate strategies compared to a more conventional strategy. One enhanced climate policy scenario relies, in particular, on raising the annual pace of energy efficiency improvement. The other aims at a radical boost of the market share of renewable energy forms, which, however, presupposes an equally radical improvement of energy efficiency.

The present article presents the scenario results and places them in the context of *risk characterisation* of the considered climate policy scenarios. Risks of international turmoil and energy price hikes could be reduced if dependency rates for fossil fuel imports went down. A more ambitious climate policy can also strengthen the EU position in post-Kyoto global climate agreements and a moderated need for emission trading can, for example, reduce conflicting pressures on clean technology transfer.

On the other hand, the implementation of the efficiency strategy will entail increased domestic risks because it will involve a re-prioritisation of resource allocation and will thus affect the current distribution of wealth in both the energy sector and some other closely related sectors.

The article outlines the main drivers behind the ambitious energy efficiency scenario and it attaches tentative price tags to the ancillary effects, with special emphasis on the above sketched swapping of risks. It will, therefore, strongly argue for a more holistic view, which underscores the need for political action and the benefits of such proactive policies in favour of energy efficiency.

Introduction
The era of cheap conventional energy resources seems to be coming to an end (e.g. ASPO, 2006; Bentley, 2006). This means that maintaining reliable supply levels requires significant and timely investments in new and more expensive oil and gas production facilities. This will put increased pressure on world market prices for oil, gas and, to a lesser extent, coal. In turn, these changes are expected to have noticeable, detrimental impacts on economic development in a business-as-usual context. Furthermore, the geographical concentration of oil and gas resources, combined with large, emerging, oil importing economies (i.e. China, India) can be expected to intensify international competition for market access to the declining resources. Last but not least, history teaches us that intensifying competition for strategic energy resources often has adverse effects on geopolitical stability, which, in turn, tends to slow down global economic development.

In addition to these strategic energy availability issues, climate change has emerged as a second challenge. It requires very substantial reductions in global greenhouse gas emissions, which essentially boils down to using less energy and switching to carbon neutral energy carriers. Since there is a growing sense of urgency with respect to realising fundamental changes in the global primary energy mix in order to avoid dangerous levels of climate changes, the analysis of energy supply strategies and climate policy strategies has become heavily intertwined. In this context, the risks of not achieving the necessary emission reductions (in time) must be pondered alongside the risks of huge, ineffective energy investments and/or of large reallocations of wealth in societies.

Traditionally, energy strategies generally tend to stress supply side solutions, which, due to scale economies, often also entail some degree of centralised production. The BAU scenario, by and large, follows that pattern, despite enhanced attention to energy efficiency. Such an approach often results in somewhat lower macro-economic cost in the short and medium-term. However, given the expected far reaching emission reductions, it is not necessarily economically advantageous in the long-term due to a lack of new (yet to be developed) clean technologies and the larger implied dependence on *both* fossil fuel imports *and* global emission trading. In the long run, this is probably not only more costly, but also makes the European (and the global) economy more sensitive to price shocks, fossil fuel supply disruptions and geopolitical turmoil linked to safeguarding fossil fuel supplies. The Nuclear+ & Carbon dioxide Capture and Storage (N^+ & CCS) variant of BAU aims to ease the pressures by means of supply side solutions, but it has only a limited potential to do so.

The EE scenario tries to create larger markets for innovative energy saving technologies and for renewable energy technology (e.g. seasonal heat storage in the built environment). In the RE scenario, apart from a strong boost of the deployment of renewable energy technology, energy savings are further intensified. In both scenarios, the future supply of new, low-carbon technologies is well facilitated, and at the same time, decreases dependency on fossil fuel imports and global emission trading[1]. The higher development and deployment costs through 2020 enable a larger technology transfer base after 2020, with a diminished need for tradable permits than in BAU. Consequently, overall energy and climate strategy cost developments are milder in the long run, while volatility is also reduced.

This paper argues that, in comparison to BAU, the EE (and especially the RE) scenario clearly mitigates the external threats of economic volatility and geopolitical turmoil but, on the other hand, imposes greater challenges with respect to the management of the more radical changes inside domestic European society (i.e. the EU and its Member States). The paper contends that it may well be worth weighing in these risks when comparing strategies as a part of a more enriched social cost-benefit analysis (i.e. including ancillary environmental benefits).

1. In BAU, the larger use of global emission trade initially implies lower cost, but is later confronted with higher costs due to a lack of new technologies. New technologies (after 2020) need to be transferred to e.g. CDM countries and then be used to create more tradable permits. This would mean that permit prices in BAU rise sharply after 2020 and than, with considerable delay, incite new energy technology development. In EE, the higher development and deployment cost through 2020 enable a larger technology transfer base after 2020, with the need for tradable permits smaller than in BAU (but still substantial). Consequently, cost developments in EE are milder in the long run and volatility is reduced.

A sustainable energy scenario for the EU

METHODOLOGY AND SCOPE OF THE SCENARIO ANALYSIS

The so-called 'two degree target'[2] implies that risk and uncertainty are no longer symmetric. In hindsight, fifty years from now, the EU member countries might decide that a slightly less hefty pace of change would have sufficed, which, in strategy analysis, may be regarded as *'regret cost'*. If, however, fifty years from now, the EU member countries have to acknowledge that climate change has not been contained sufficiently, it would entail a *more serious regret cost*. This justifies a tightening of measures in the EU as part of a global transformation aiming at a sustainable low carbon economy[3].

Even though the Stern report may have produced rather optimistic cost-benefit ratios with respect to early action to prevent larger damage later[4], it still provides a good basis for the development of early action strategies. It shows that global emissions trading is an important instrument, but that it needs adjacent policies in order to ensure a long-term supply and the global spread of low and non-carbon technologies. An emission abatement strategy that stresses short-term and medium-term cost minimisation runs the risk of maximising the use of emission trading (EU ETS, CDM, etc.) without ensuring that new technologies can gradually build up a track record. The latter is needed to enable emissions reductions against affordable cost in later stages of the transition towards a sustainable economy. A long-term, continued supply of such technologies requires a set of policies that incites sufficient and effective research, development, and deployment of renewable energy and energy saving technologies.

A set of scenarios was specified for the EU25 that covered alternative strategies and targets indicated by the European Parliament Committee on Industry, Research and Energy (ITRE). Based on recent work for the European Commission (see below), the alternatives represent a range of strategic technology choices as compared to a reference (BAU) scenario, including more or less nuclear, carbon-dioxide capture and storage, enhanced energy efficiency, increased use of CHP and maximisation of the use of renewable energy sources. Altogether, five different scenarios were developed (Lechtenböhmer et al., 2006).

The analysis was based on two main sources. The basic data, economic assumptions and the main results for the BAU scenario were derived from the latest available EU energy and transport projections (Decker 2006, Mantzos 2006, Mantzos & Capros 2006). Demand-side projections and analyses of higher penetrations of energy efficiency and renewable energies were derived from a recent scenario analysis by the Wuppertal In-

2. Average global temperature rise of more than 2 degrees centigrade is assumed to significantly increase risks for more serious damage due to climate change as well as for irreversible phenomena with grave effects (e.g. release of methane due to vanishing of permafrost).

3. Some argue that it doesn't pay off for the EU to be in the driver's seat of this global change process. The prevailing view among specialists has been that the realisation of the Kyoto Protocol and the current post-Kyoto investigations essentially depend on the role of the EU as trail blazer. Admittedly, neither this majority view nor views that call for a more cautious strategy can be evidenced with socio-economic simulations. They can only be argued.

4. There are publicly available (but mostly not peer reviewed) reviews from, among others, Nordhaus, Tol, Dasgupta, and Varian. Even though there are indications that some of the criticism, e.g. regarding discounting, is based on misunderstandings, the overall judgement is that, due to various key choices, a rather favourable cost-benefit ratio for early action (as central estimate) has been produced.

Table 1: Comparison of the scenarios – changes from 1990 to 2030 and the situation in 2030

Scenario	CO_2 emissions (% Δ 1990)	Primary energy supply (% Δ 1990)	Import dependency*)	Nuclear share of electricity generation	RES share in PE supply	Energy efficiency growth rate (2000 - 2030)
BAU	+4.7%	+14.6%	64.8%	18.7%	12.2%	1.5%
N^+ & CCS	+1.3%	+16.4%	62.7%	23.6%	12.0%	1.5%
Energy Efficiency (EE)	-18.8%	-8.2%	59.8%	15.7%	15.0%	2.2%
Renewable Energy (RE)	-45.1%	-20.1%	49.1%	16.4%	31.4%	2.7%
Starting point (2000)	-3%		47%	14%	6%	-
*) As percentage share of primary energy consumption, nuclear fuel imports not included						

Source: own calculations, Lechtenböhmer et al. 2006

stitute (Lechtenböhmer et al. 2005a/b). The quantification and combination of potentials, costs, strategies, policies and measures, and the calculation of scenarios have been carried out using the Wuppertal Scenario modelling system.

DESCRIPTION OF CORE CONTENTS OF THE SCENARIOS

In order to draw different possible futures of the EU energy system, five exemplary scenarios were designed according to the definitions requested by the EP. In table 1, four scenarios are shown: BAU and N^+ & CCS (a variant of BAU with extra nuclear and CO_2 capture and storage) as well as two alternatives, the Energy Efficiency (EE) and the Renewable Energy (RE) scenario.

In the **business as usual (BAU) scenario,** which has been developed to be compatible with the most recent baseline scenario of the EU Commissions Directorate-General Energy and Transport (Mantzos & Capros 2006), the continuation of energy policy trends would already lead to a strong primary energy efficiency increase within the EU25. However, this increase would not be sufficient to compensate for a growing Gross Domestic Product (GDP). As a consequence, primary energy demand would increase by almost 15 % and import dependency by more than a third. Due to an increased share of renewable energy sources (RES) and a switch to natural gas, the increase of CO_2 emissions is limited to 5 %. Various Member States could depart from their current official stances regarding new nuclear capacity. Furthermore, carbon capture and storage is very rapidly getting more R&D funding. If new nuclear capacity were built and CCS technology were introduced, the emissions would only rise at just over 1 % compared to the 1990 level **(N+ & CCS)**.

With regard to climate policy, the BAU scenario assumes that the EU25 will accept international emission reduction targets of 15 % by 2020 and 30 % by 2030 for the commitment periods after 2012[5]. These targets are also effective in the alternative scenarios. The consequence is that by 2030 in BAU, the EU25 has to buy a total of approximately 35 % quota of its 1990 emission levels as tradable emissions from outside EU25. In N+ & CCS, this decreases to 32 % and in EE, is down to just over 11 %. In RE, more ambitious reduction targets would be feasible and/or the EU25 group would not need to buy emission quota from elsewhere (or even be a net seller, in theory).

In the **energy efficiency (EE) scenario, it** is assumed that active energy policy gets implemented in all energy demand sectors as well as on the energy supply-side (see table 2). In effect, these policies and measures lead to a doubling of the EU25's primary energy efficiency with 10.5 M euros saved per ktoe by 2030. This is equivalent to energy savings of almost 20 % compared to the BAU scenario.

The investments for this strategy are supposed to be paid from the cost reductions of energy imports and the cost reductions in the EU energy system. The latter reductions are, first and foremost, linked to lower investments for power plants and energy infrastructure. Other analyses by the Wuppertal Institute (2006a) show that this would be possible and cost efficient.

Benefits of this strategy include the furthering of the achievement of the following strategic objectives:

- CO_2 emission reductions within the EU equal to half of the 20 % reduction lower bound in 2020 as proposed by the European Commission and continued growth after 2020 such that the high level of dependency on international emission trade, as in the BAU scenario, is substantially reduced.
- A modest increase in the share of renewables compared to BAU.
- A significant reduction of the import dependency, vulnerability to high energy prices and possible supply shortages.

The **renewable energy (RE) scenario** describes a much more fundamental restructuring, leading towards a highly efficient and renewable energy based economy. The scenario combines a very ambitious drive towards energy efficiency (11.9 MEur/ktoe by 2030) with an accelerated expansion strategy for renewable energy sources. Renewable energy supply is projected to reach a share of 31 % of total primary energy supply in 2030. In the RE scenario, a rapid implementation of improvements in energy efficiency is assumed, as described by Lechtenböhmer et al. (2005a/b). This development would lead to an acceleration of 80 % of energy efficiency and, by 2030, to a level of primary energy efficiency 50 % higher than in the BAU scenario. Final energy demand would be reduced by 33 % and electricity demand by almost 24 % in 2030 compared to the BAU scenario. This strategy depends on the feasibility of accelerating energy

5. These figures are consistent with the Council Decision from May 2005 (EU 2005). After conclusion of the study in January 2007, the European Commission announced reduction targets of 20% - 30%, which were set by the Council in March 2007.

Table 2: Energy efficiency in the EU25 in different scenarios

Year	2000	2010			2020			2030		
Scenario	BAU	BAU	EE	RE	BAU	EE	RE	BAU	EE	RE
Gross Inland Consumption (Mtoe / %vs. baseline)	1654	1813	1721 -5.1%	1707 -5.8%	1885	1654 -12.3%	1575 -16.5%	1895	1528 -19.4%	1350 -28.8%
Final Energy Demand (Mtoe / %vs. baseline)	1095	1238	1160 -6.3%	1102 -11.0%	1339	1173 -12.3%	1045 -21.9%	1370	1119 -18.4%	919 -32.9%
Energy intensity indicators (1990=100)										
Industry (Energy use / Value added)	83.6	77.3	70.5	68.2	66.7	56.6	53.2	58.5	46.6	42.7
Residential (Energy use / Private Income)	85.9	80.4	72.9	70.4	70.6	60.0	56.4	62.5	49.6	45.3
Tertiary (Energy use / Value added)	85.4	79.6	78.3	76.8	70.6	61.8	55.1	63.4	47.4	36.0
Transport (Energy / GDP)	85.4	93.0	90.0	76.8	79.3	74.1	55.1	66.9	60.3	36.0
Primary energy efficiency (MEUR/toe)	5.3	6.0	6.4	6.4	7.2	8.3	8.7	8.5	10.5	11.9
CHP indicator (% of electricity from CHP)	14.4%	16.8%	15.3%	17.8%	21.4%	22.9%	27.9%	24.6%	29.5%	39.6%

Source: own calculations, Lechtenböhmer et al. 2006

efficiency improvement to 2.7 % per year and on the feasibility of the projected 34 % share of fluctuating energies (wind, hydro, solar, tidal and wave) in the electricity system. The RE scenario, therefore, describes an ambitious strategy which is supposed to deliver a number of important political targets such as:

- Ambitious CO_2 emission reductions that ensure fulfilment of the post-Kyoto reduction targets.
- Achievement of the renewable energy and CHP capacity expansion targets.
- A substantial reduction of import dependency, vulnerability to high energy prices and possible supply shortages.

ENERGY EFFICIENCY POLICIES AND IMPLIED TRENDS IN THE SCENARIOS

In the BAU scenario, energy efficiency in all demand sectors only improves at approximately historical rates, ranging from 0.8 % per year in transport to 1.2 % in industry. In the EE scenario, a portfolio of policies (discussed below) boosts this trend by about 50 % to -1.2 % in transport and to 1.9 % in industry. A remarkable acceleration of energy efficiency is to be achieved in the tertiary sector. Here, energy intensity improvements can be almost doubled to -1.9 % per year (see also table A1 in the Annex). In the RE scenario, particular emphasis has been placed on further improvement of energy efficiency in the transport sector and the tertiary sector. It should be stressed that these are *average* figures for EU25. The improvement potentials per sector (in terms of %/year) vary considerably across Member States.

As a corroboration of the Wuppertal Institute model findings for efficiency, we refer to a recent study by Daniëls et al (2006) based on up-to-date information for the Netherlands. That study indicates that, for the Netherlands, an annual improvement of primary energy efficiency of about 2.1 % constitutes the feasible upper limit and is about 1.6 times the current pace of improvement. The 2.1 % per year can be subdivided into 0.5 % for energy conversion and 1.6 % for final energy use. Considering that the Netherlands has been relatively active in energy saving for well over a decade, it is likely that the country's currently feasible pace of efficiency improvement is below the feasible upper limit for the EU as a whole. Furthermore, recent work related to the applicability and instrumental efficiency of tradable white certificates (Perrels and Tuovinen, 2007) illustrates that, even for a country like Finland, with technically efficient energy use and rather low energy prices, there is still a significant affordable energy savings potential that has remained untapped thus far.

The pace of energy efficiency improvement has to be increased by at least 50 % in comparison to BAU. This requires a comprehensive policy package that goes beyond energy efficiency policy[6]. Key elements, often building on existing directives, are:

- The Directive on energy end-use efficiency and energy services, which could be amended to set mandatory (overall) efficiency targets of at least 1 % per year and if need be, can be elaborated with the introduction of a tradable white certificate system (either country level or multi-country level).
- The Directive on eco-design requirements for energy-using products can be used to regulate strong minimum efficiency standards, e.g. by including the top-runner approach or by including external costs into the determination of the lowest life-cycle costs.
- A new framework Directive on energy labelling, which could introduce dynamic efficiency classes and cover an increasing amount of products, including cars.
- Ensuring national implementation and further revisions of the Directive on the energy performance of buildings (see

6. For a broader discussion of policies see Lechtenböhmer et al. 2005a/b and Wuppertal Institute (2006). A preliminary discussion of the measures planned in the EU Action Plan on Energy Efficiency can be found in Scholten et al. (2007), paper 2,205 in eceee summer study 2007.

also Bowie et al, 2003) as well as inclusion of the electricity consumption of the installed equipment in the regulation schemes.

- Promotion of CHP-based district heating systems, including the salvation and refurbishment of these systems in various new Member States, the lifting of barriers to CHP in current national legislations and the promotion of micro-CHP in conjunction with the use of (local) renewable energy sources.
- Fiscally neutral energy taxation for users outside EU-EUS, i.e. by compensating energy tax raises via income tax and or social-security levies (a possible alternative for tradable white certificates, depending on a country's circumstances).
- Promoting the use of Demand-Side Management (DSM) and Demand-Side Bidding, i.e. through guidelines for retail tariff structures.
- Financial incentive programmes in order to accelerate renovation and dynamic improvement of dwellings.
- Differentiated vehicle purchase taxes and annual road taxes by fuel performance and emissions.
- Continued voluntary agreements with car makers for further emissions reductions of newly sold cars in the post-Kyoto period (e.g. to 100g CO_2 per vehicle km in 2015).
- Promotion of spatial planning at the local and national level that economizes the need for mobility, introduction of congestion taxes where relevant (in conjunction with the promotion of adequate public transport) and promotion of clean urban logistics (without spurring relocation outside the inner city).
- Consideration of an emissions reduction scheme for the aviation sector or inclusion of civil aviation in the EU Emission Trade System (provided the use of grandfathering is greatly reduced).

Furthermore, the introduction of energy saving funds in all Member States following Danish and British examples and the definition of individual savings targets for energy suppliers under the framework of the energy end-use efficiency as already present in the UK, Denmark, Italy and Flanders could be introduced (see also the first bullet point above). The EU CO_2 Emission Trading Scheme should also be better combined with energy efficiency policy.

With regards to stationary RES technologies research, development and demonstration policies should emphasise synergies with efficient building technologies (integrated approaches, see EE scenario). A specific work topic is foreseen under FP7 for renewable heating and cooling. With regard to further exploitation of distributed generation (CHP), grid connection plays a major role. Work under the FP7 topic of smart energy networks and the ETP Smart Grids has to provide solutions to this aspect. The potential for seasonal storage in conjunction with sustainable building design also deserves attention in European and national programmes for research, development and demonstration.

Particularly after 2010, cogeneration must become the major investment area in EU electricity generation capacity. The following measures are needed

- Stronger support for the investments and the technology, e.g. by an adequate support of CHP in the EU Emission Trade System, by an amendment of the CHP Directive in order to set (mandatory) targets for further periods (2020 EE: 23 %, RE: 28 %), by a supportive framework for investment in industrial and municipal CHP plants, and by precise rules and conditions for electricity feed-in, stand-by and residual power prices.
- Less restrictive planning regulations for small CHP plants in decentralised district heating systems, e.g. in new residential, commercial or industrial developments.
- A scheme for accelerated development, technological improvement and market introduction of micro CHP units, comprising, for example, the inclusion of CHP friendly rules in building codes, soft loans and other subsidy schemes.

RENEWABLE ENERGIES

In all scenarios, a very active EU policy to promote renewable energies is assumed. As the analysis of the existing policy shows, broad additional activities are indispensable even in the **BAU scenario**. However, in this scenario, targets are likely to be missed and the EU would have to solve the problem of fostering a supportive framework for renewable energies in a late stage, while many (less favourable) investments will have already been made.

In the renewable energy scenario (RE), on the other hand, both current targets and ambitious targets for the future (20 % in 2020, 35 % in 2030) can be achieved. However, these targets require a substantial restructuring of the whole energy system and of the economy by using the window of opportunity presented by the ageing energy system and its subsequent high reinvestment need. It appears that current policy for renewable energy, in spite of its successes, is not yet in a position to roll out the changes needed for the realisation of this scenario.

The RE scenario assumes more than a doubling of growth of renewable energy production compared to BAU, while neutralising energy demand growth by intensified energy efficiency policy (see above). Renewable energy supply reaches a share of over 30 % (50 % in electricity generation) in 2030 (see also table A2 in the Annex). This, however, demands a strict, radical and comprehensive policy at EU and Member State level. Policies could, for example, include binding targets for all Member States and for all market segments.

In addition to BAU developments the RE scenario demands more concerted research and technology support efforts mainly in the field of biofuel use, biomass CHP and renewable heating and cooling technologies. All of these themes are closely linked to full exploitation of EU biomass potentials. In order to increase the share of renewable energy based electricity beyond the level of the BAU scenario, R&D under the FP7 topic, renewable electricity, needs to open up the market opportunities for geothermal electricity (e.g. Hot-dry-rock).

RE in power generation

In the RE scenario, the electricity industry has to use the necessary reinvestment of power generation capacity to achieve a complete restructuring. Investments in condensing power plants will almost cease, apart from gas fired CGTs. Instead, investments must be made in CHP (biomass and gas-fired) and in greater renewable capacity.

This requires clear political decisions and probably stricter instruments for redirecting investments (such as restrictive permits for new condensing power plants, investment support for new biomass fired CHP, support for market introduction of new renewable technologies and development of offshore wind farms and solar thermal plants. Additionally, stronger and more wide-spread supporting schemes (feed-in tariffs, quotas or certificates) are needed.

RE in transport sector

The RE scenario almost achieves the target of 5 % biofuels in 2010 and leads to a 25 % share in 2030. This achievement requires strong policy (i.e. binding targets for biofuel shares) aimed at a substantial increase of biomass shares in mixed fuels (including technical development of motors etc.) and financial incentive schemes to promote market penetration of cars running on pure biofuels. The promotion of biofuels should avoid pitfalls such as guarding the ecological integrity of biofuel chains involving developing countries and acknowledging that optimalisation may require diversity within the EU (e.g. focus on energy crops in Western Europe and on wood residuals in Northern Europe).

Renewable Heat

Direct biomass use and solar thermal systems will achieve a share of 16 % of final energy (without electricity and district heat) in stationary applications. Applicable technologies are solar thermal devices including high temperature and solar cooling as well as biomass fired heating systems and micro CHP systems.

This implies that specific targets and instruments are needed for this market segment. Possible instruments include the introduction of RES obligations in building codes, provision of soft loans, combination of RES with building refurbishment, feed-in such as financial support schemes and obligations for businesses.

Biomass

The strong policy towards renewable energies in the RE scenario will almost fully exploit the EU biomass potential. This requires the upgrading of indicative targets to binding targets, an improved integration of biowaste use and biomass production into agricultural policy, the provision of incentives and the promotion of the development of processing infrastructures. Apart from this, sustainability criteria should be developed and implemented to ensure environmentally sound biomass production in the EU and in exporting countries.

COMPARISON TO RECENT DG TREN SCENARIOS

DG TREN commissioned a study on long-term energy scenarios (Mantzos and Capros, 2006), which included alternative strategies with high ambition levels for energy saving and renewable energy use. Mantzos and Capros (2006) developed three scenarios, one efficiency scenario, one renewable scenario and a so-called "Combined" scenario. The outcomes of energy efficiency are almost equivalent to those of the EE scenario[7], when considering -12 % (-13 %) primary energy efficiency vs. BAU in 2020 and -19 % (-20 %) in 2030 (see also table A3 in the Annex). The expansion of renewable energies in the 'Combined' scenario by Mantzos et al., is, in absolute terms, similar to the RE scenario, yet differs from the RE scenario, which allows for a substantially larger improvement of energy efficiency.

All in all, the scenarios can be ranked according to the following sequence of rising ambitions: EE- high energy efficiency + renewable energies as in BAU; 'Combined'- intermediate energy efficiency + renewable energy expansion, RE- maximum energy efficiency + renewable energy expansion.

Economic Benefits of Energy Efficiency

Energy efficiency as a core alternative to the BAU scenario delivers substantial economic benefits. The more tangible benefits are:

- Reduced import dependency, which lowers the energy import bills in the EE scenario by 24 billion euros in 2020 and by 54 billion euros in 2030, with similar decreases found in the RE scenario, in which fossil fuel import costs go down by 73 billion euros in 2020 and 140 billion euros in 2030 (see also table 3 below).
- Reduced vulnerability of the EU economy towards energy price shocks. A lower energy intensity and a much lower cost share for fossil fuels implies that price shocks have much less effect on the economy (see table 4 and accompanying text above it).
- Mitigation of high investment needs in electricity generation and energy infrastructure by between 1.1 % and 1.5 % of total GDP in the EE and by between 1.9 % and 3.3 % in the RE scenario. This investment, however, will be needed for increased investment in energy efficiency (see also next section).
- A 20 to 45 billion euro per year reduction of CO_2 emission rights costs to be purchased by international emission trading, depending on the time horizon, scenario and emissions target (see table 3).
- The less tangible, but not necessarily small, benefits are:
- Due to strongly reduced fossil fuel use, the external costs of the energy production and consumption can be expected to be significantly lower than in the BAU scenario (i.e. public health effects).
- Increased investment in energy efficiency technology instead of infrastructure and fossil energy imports has the potential to create new jobs due to higher labour intensity and a higher share of domestic value added. This effect, however, may vary significantly across Member States and regions. For example, an increasing number of Member

7. The higher share of renewable electricity generation in the Combined scenario leads to higher energy efficiency at the primary energy level (due to 100 % efficiency of renewable power generation). At the level of final energy use, however, both scenarios should be quite comparable.

Table 3: Import dependency, value of energy imports and costs of end use energy and CO_2 permits in the EU, 2000 – 2030, aggregated results

	2000	2020			2030		
Scenario	BAU	BAU	EE	RE	BAU	EE	RE
Import dependency (without nuclear imports)	47%	64%	58%	50%	65%	60%	49%
Solids	31%	58%	33%	32%	66%	34%	30%
Oil	82%	93%	92%	91%	94%	93%	90%
natural gas	50%	81%	80%	75%	84%	82%	77%
Biomass	0%	0%	0%	20%	0%	0%	20%
Base price scenario							
Value of energy imports (bln $€_{00}$)		301	277	228	358	304	218
Energy costs of end use sectors (bln $€_{00}$)	n.e.	1046	908	794	1096	878	664
in % of GDP		7.7%	6.6%	5.8%	6.8%	5.5%	4.1%
High price scenario							
Value of energy imports (bln $€_{00}$)		499	462	378	623	533	382
Energy costs of end use sectors (bln $€_{00}$)	n.e.	1175	1019	886	1290	1034	769
in % of GDP		8.7%	7.4%	6.5%	8.0%	6.5%	4.7%
Cost for acquisition of tradable CO_2 permits (bln $€_{00}$)	n.e.	25	5	(-4)	29	7	(-16)

Source: own calculations, Lechtenböhmer et al. (2006), Price scenarios from Mantzos & Capros (2006)

Table 4: The accumulated (5 year) value of reduced sensitivity to an oil price shock induced reduction in GDP growth (in billions of euros)

shock happening around the year:	RE	EE
2020	200	93
2030	300	156

Source: Own calculations applying scenario growth rates and elasticities from Jimenez-Rodriguez (2004)

States is facing a shrinking work force and, consequently, labour intensive solutions could cause wage inflation due to competition for workers.

- The EU has the potential to profit from first mover advantages, as the solutions for higher energy efficiency will be needed in other countries as well.
- The appreciable lowered dependence on imported fossil fuels provides leeway in terms of choice of production location and tensions on the oil market are, thus, harder to exploit for long periods. This could cause the need for geopolitical interventions to drop and, in turn, fewer options for (or less reasons for) destabilisations may contribute to a more favourable global socio-economic development.

Illustrating the benefits of reduced fossil fuel import vulnerability

According to Jimenez-Rodriguez and Sánchez (2004), an oil price shock of a 100 % increase causes a reduction in GDP growth of 2 % to 5 % for various EU countries[8]. The analysis indicates that the impact fades away gradually over a period of five years. If we assume a 50 % price shock in oil prices (which is well within the ranges of experienced shocks), an average initial loss in GDP growth of about 1.5 % can be assumed with current levels of import dependence. In the BAU scenario, the import dependence increases both in relative and absolute levels, whereas it goes down in EE and even more in RE. The shock effects attenuate commensurate with the reduction in the import shares. This effect gets even stronger after correcting for the overall reduction in primary (fossil) energy consumption. The figures below in table 4 should be multiplied by the likelihood of a major oil price shock. Through 2020, that likelihood is substantial, e.g. 50 %, while for the period up to 2030, it gets very likely that at least one major oil price shock will have occurred. Table 4 below shows that implementation of the RE scenario would mean that the occurrence of an oil price shock in or around 2020 would cause a 200 billion euros reduction in GDP loss of the EU25 than the same in the BAU scenario.

Apart from benefits, the alternative scenarios cause also extra costs due to loss of sales in the energy sector and large amounts of incited investments in energy savings and renewable energy conversion capacity. In the next section, the net benefits are presented.

Domestic change management as a risk mitigation strategy

Towards a reorientation of investment portfolios in the energy system

One of the major challenges of the EE scenario, and especially the RE scenario, is the realignment of investments. This is a challenge in not only terms of policy instrument design and market design adaptations, but also in terms of strategic leadership in the rebalancing of interests, which not only maintains order but strives to prevent undue harm to particular sectors as well.

The current energy system in the EU, though not entirely liberalised, aims to maximise medium-term profits by build-

8. The size of the interval of shock responsiveness figures is partly attributable to differences between countries and partly due to testing the relations with various estimation methods.

ing an appropriate volume and mix of energy supply capacity. It is possible to insert market incentives in the system such as demand-side bidding, strict separation of network service pricing from actual energy delivery, emission cap and trade systems (provided there is a high level of auctioning), separate wholesale pricing of capacity with some differential treatments favouring clean conversion options and auctioning of investment subsidies for new renewable energy-based capacity. Without explicit transformation policies, however, the energy supply system will not pursue truly vigorous energy savings nor will it aspire to very high shares of renewable energy forms unless these are commercially attractive (as hydro power and biomass may be in some cases).

Energy taxation in combination with tax recycling can help to motivate energy saving actions without harming the economy but beyond a certain level, the side effects start to weigh in quite heavily and effectiveness starts to decline. On the other hand, if energy suppliers notice that demand for energy is stagnating, they may suspend investments and invest only in minimal upkeep of the existing stock since, under stagnating market circumstances, an approach of 'withholding' produces the best opportunities for short to medium-term profit maximisation. As a consequence, the pace of renewal slows down considerably and, hence, the scope of reducing the emission intensity of the energy supply becomes drastically worse. Another consequence could be further concentration of the capacity into fewer hands, i.e. increase of monopoly power.

Instruments that provide incentives to the energy supply sector are needed for continued investment in clean conversion capacity *and* in the capacity to save energy, despite the fact that the (physical) volume of their energy sales is diminishing. The competitiveness of markets could be maintained by promoting building and energy technologies that pursue the joint optimisation of energy savings and use of local renewable resources, both in the built environment as well as in various industries. In the built environment, for example, technologies such as passive sunlight, solar collectors, PV-panels, natural ventilation, biomass run micro-CHP, high insulation standards, heat recovery and seasonal storage of surplus heat could be utilised. The embodied energy and emissions of building materials could be accounted for as well. Incentive structures should stimulate energy companies to take part in investments in the built environment and certain industries, with the aim of creating new clean-energy resources, allowing for energy savings while enabling energy companies to stay in business.

In addition to effective policies that reorient a significant part of energy related investment flows from the supply to the demand-side, there are also timing and uncertainty aspects that must be taken into consideration. In the EE scenario and particularly in the RE scenario, the unit-cost of energy production capacity (or conversely, savings capacity) increases. The overall effect may be that the up-front costs rise while the revenue base narrows. Assuming that the main features of the liberalised market are retained, this means that there is uncertainty as whether the energy prices will rise enough to compensate for the lower volumes. Another uncertainty is that the benefits of a more stable economy, thanks to lower sensitivity to price shocks, are uncertain in terms of size, time-profile and the particular sectors in which benefits accrue. Mixed with these uncertainties are questions of how well a new policy incentive structure will succeed in reallocating the investment flows and to what extent changes in market power may cause new concerns about new concentrations, e.g. due to a growing dominance of big players from the financial sector.

What do the benefits and costs add up to?

As previously mentioned, the substantial changes and reductions in energy demand enable a gradual release of funds, originally meant for the supply-side, for reallocation to other purposes. The following items make up possible sources of 'fund release':

- Energy imports (mainly constituting a reduction in costs for the energy conversion sector, see table 3).
- Reduced supply capacity investments known as the volume effect (mainly a reduction in costs for the energy conversion sector).
- Reduced cost of emission trade (see table 3).
- Reduced energy acquisition cost for end-users (a cumulative effect containing the aforementioned issues, see table 3)
- Ancillary benefits of other reduced emissions (not quantified in this study).
- Implied benefits of more stable economic growth (occurrence and timing uncertain, see table 4)

It was illustrated in section "Economic Benefits of Energy Efficiency" that the 'released funds' add up to considerable amounts, although the ambitious targets for energy savings and elevated use of renewable energy sources also entail significant costs such as:

- More expensive energy supply capacity or the unit-cost effect, meaning that a part of the small-scale, installed capacity is more expensive per MW than the original capacity foreseen in BAU (a significant cost for the energy supply sector, but growing self-generation in end-use sectors implies also extra need for funds among end-users).
- More expensive end-use equipment, meaning that, despite learning effects, various types of equipment and, possibly, various kinds of buildings, will get more expensive due to more embodied human capital (knowledge) and high-tech materials (typically a cost for infrastructure and equipment builders, as well as end-use sectors, not including policies that involve the energy supply sector).
- Induced cost effects in some sectors following from higher unit-cost of energy and from land use effects of expanded biomass cultivation (in some sectors such as those with limited energy saving options, the higher unit-cost of energy will be transferred to the prices of products and services and similarly, the elevated demand for biofuel input may increase the cost of wood, land and some food staples).
- Expanding energy R&D and precipitating market uptake (i.e. pilot project support) to ensure continued supply of affordable energy saving and renewable energy technology.

Table 5 summarises the estimated pros and cons discussed above. The figures denote a difference as compared to the BAU

Table 5: Accumulated net macro-level cost differences of EE and RE compared to BAU

Whole period 2010 – 2030	Base oil price		High oil price	
Cost items	EE	RE	EE	RE
Energy acquisition costs for end-users (-/- 35% value added ESI)*)	-1820	-3426	-2340	-3861
Extra R&D efforts, notably, for energy efficiency & renewables	50	70	50	70
Investments in energy savings **)	1340	3340	1340	3340
Total 1	***-430***	***-16***	***-950***	***-451***
Benefits of the reduction of oil price sensitivity	-156	-300	-156	-300
Total 2	***-586***	***-316***	***-1106***	***-751***

Negative values = benefits, positive values = costs
*) Corrected for the overall loss in gross value added in the energy supply sector (~ 35%)
**) Estimated based on cost information of the Eurowhitecert study (Perrels et al. 2007). An EU wide average unit-cost is used for a given fraction of the potential and the fraction in RE is higher (=100%) than in EE, hence a higher average unit-cost. Includes the transport sector.

Source: own calculations; N.B. apart from the correction for loss of value added of the energy supply sector, no other induced economic effects have been considered (that would require a detailed CGE model covering all member states).

strategy. The table shows a preliminary and fairly conservative estimate in which additional investments for more energy efficient technology along with the higher costs of the more expensive (renewable) power plants can be covered by the cost savings in final energy consumption. The total net benefits could even amount to as much as 1100 billion euros for the scenario period as a whole. Here, the EE scenario seems to be more advantageous because of the cheaper cost of investment in energy efficiency and the renunciation of investment in the more expensive renewable energy supply. When the benefits of a reduction in oil price sensitivity are added to the balance, the advantage of the alternative strategies becomes even clearer. The difference between the EE and the more ambitious RE strategy, however, lessens as higher efficiency and expanded, domestic, renewable energy supplies deliver higher benefits with regards to world energy supply risks. It seems, therefore, that the advantages of both strategies are virtually always sufficient to cover the additional transaction costs delivering energy efficiency, restructuring the EU energy system and covering additional R&D needs. With respect to the presented cost effects, it should be stressed that no overall macro-economic impact assessment has been carried out that could test whether it matters (or the extent to which it matters) if energy end-users or the energy supply industry experience an initial reduction in value added.

Conclusion

A radical change towards a sustainable energy system is, on the one hand, a challenging strategy and, therefore, constitutes risks of failure both with respect to ecological targets and to conditions covering the other sustainability dimensions such as economy and social well being. In this respect, the scenarios discussed in this paper illustrate that substantial increases in energy efficiency and in renewable energy use do not have to cost more to society than a continuation of Business as Usual approaches.

On the other hand, a status quo (as embodied by BAU) is often, deceptively considered as safer, although it, too, implies risks. In the cases described in this paper, the risk of BAU lies principally in its failure to achieve sufficient reductions in greenhouse gas emissions. This type of strategy (like BAU and N^+ & CCS in this study) tends to rely predominantly on optimisation of large and medium-scale energy conversion technology.[9] Yet, while not denying the useful role of these advanced supply-side technologies (not the least in developing countries with fast growing economies), the scenario discussion provides reasons for serious concerns about the amount of emissions reductions and fossil fuel decoupling that these BAU approaches can eventually deliver. Furthermore, apart from missing strategic ecological objectives, the failure to reduce fossil fuel import dependence and the large dependence on emission trading point at increasing economic vulnerability as time passes by in the BAU scenario.

Up to now, BAU type strategies are often still preferred as the economic implications of alternative scenarios are perceived to be problematic. The scenarios discussed here illustrate that, when policy making starts to require the inclusion of longer term effects, the extra efforts for ecological sustainability do not have to lead to inferior economic performance. Basically, the savings on energy acquisition cost and on reduced investments for energy conversion capacity release sufficient purchasing power for extra efforts in energy efficiency and renewable energy use. What remains, is the challenge of initiating the appropriate reallocation of the funds without causing undue harm to any sector. This is an undeniably difficult task. This paper has, however, indicated that there is a portfolio of both existing and new policy instruments available, although further developments regarding policy instruments, funding mechanisms and strategic governance are needed. Even in the BAU scenario, however, large managerial challenges would have to be faced.

In that respect, we claim that the EE and RE scenarios will pave the way for a swap of risks from hardly controllable external relations to *domestic change management*. They thus underscore that the recent energy strategy proposed by the European Commission (COM 2007) and concluded by the Council in March 2007[10] which targets at a 20 % CO_2 emissions reduction,

9. We do not claim that those options should be forgotten. For example, if the technology became mature, carbon capture and storage could provide interesting prospects when applied to power stations running on biomass.

10. Presidency Conclusions of the Brussels European Council (8/9 March 2007)

20 % renewable energy generation and 20 % energy savings by 2020 (or more or less a strategy as outlined in the RE scenario) is heading in the right direction and that the huge challenges posed by the realisation of these targets to policymakers and society are worthwhile and probably substantially smaller than the often overlooked challenges imposed by BAU.

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Annex – Additional information on scenario trends and assumptions

Table A.1: Energy intensity improvement by demand sector in different scenarios, 2000 – 2030

	BAU	EE	RE
Industry	-1.2%	-1.9%	-2.2%
Residential	-1.1%	-1.8%	-2.1%
Tertiary	-1.0%	-1.9%	-2.8%
Transport	-0.8%	-1.2%	-2.8%
overall average	**-1.1%**	**-1.7%**	**-2.4%**

Source: own calculations, Lechtenböhmer et al. 2006

Table A.2: Share of renewable energy sources in various energy use categories in different scenarios, by 2030

Res Share Values for 2030	total primary energy use	electricity generation	CHP generation	transport fuels	heat sector
BAU	12%	28%	14%	6%	14%
N+		27%	13%		
EE	15%	36%	15%	7%	11%
RE	31%	50%	35%	26%	20%
Res Share Values 2005		16%	5%	0,9%	10%
Res Share Values 2000	6%	15%	5%	0,1%	9%

Source: Lechtenböhmer et al. 2006

Table A.3: Comparison with DG TREN Combined high efficiency & renewable scenario

		Combined DG TREN		EE		RE	
		2020	2030	2020	2030	2020	2030
Primary energy	% vs. BAU	-13	-20	-12	-19	-16	-29
Renewable	Mtoe	325	394	186	229	315	418
energy use	%	20	26	11	15	20	31
CO_2 emissions	Mt	2969	2670	3122	2956	2795	2015
	% vs. 1990	-21.4	-29.3	-17.3	-21.7	-26.0	-46.6
Import	Mtoe			1107	1020	942	770
dependency	%	57	59	58	60	50	49

Source: own calculations, Lechtenböhmer et al. (2006), Mantzos & Capros (2006)