MNP report 500116001/2006

Sustainable energy: trade-offs and synergies between energy security, competitiveness, and environment

Berk, M.M., Bollen, J.C., Eerens, H.C., Manders, A.J.G., and van Vuuren, D.P.

Contact:
Bollen J.C.
Netherlands Environmental Assessment Agency
JC.Bollen@mnp.nl

Netherlands Environmental Assessment Agency

Netherlands Environmental Assessment Agency (MNP),
P.O. Box 303, 3720 AH Bilthoven, the Netherlands
Telephone: +31-30-274 274 5; Fax: +31-30-274 44 79; www.mnp.nl/en

Summary

Sustainable energy policy requires integrated approach

Energy is key to economic growth. Prolonged use of energy cannot be taken for granted. Concerns about energy security in the EU are growing and energy is a main driver behind climate change and local air pollution. A more sustainable energy policy can improve on energy security *and* reduce environmental impacts, like air pollution *and* greenhouse-gas emissions. Such policies incur costs to society, and may deteriorate economic growth and competitiveness. This requires a policy-mix that serves to achieve multiple goals and thus increases the efficiency of EU-policy.

There is a large scope for synergy between policies related to climate, air pollution and energy security. The mix of options and policies that maximizes this synergy can significantly improve the efficiency of EU policy.

Attractive options - from the viewpoint of synergies - include efficiency and more renewables. Trade-offs may occur; e.g. coal use to enhance energy security may result in higher greenhouse gas emissions (unless in combination with gasification and carbon capture and storage). Another example concerns bio-energy technologies, which reduce emissions of greenhouse gases, but not necessarily those of other air pollutants.

The ancillary benefits of greenhouse gas abatement policies are significant. In the case of air pollution, these may even approximate the greenhouse gas abatement costs.

There are costs involved in reducing greenhouse gas emissions, increasing energy security, and avoiding damage from air pollution. Abatement costs for stringent climate policies are likely to be in the order of 1-2% of GDP by 2030, assuming broad international participation. A shrinking coalition size - while maintaining reduction targets for its members - will lead to higher abatement costs. Large greenhouse gas emission reductions in the EU-25 will also reduce the emissions of SO_2, NO_x, and Particulate Matter. This in turn will lower the chronic exposure of European citizens to these substances. And this again is likely to reduce the number of premature deaths, chronic bronchitis, and absence from work due to illness. Moreover, estimates of monetarized benefits seem to equal the costs of greenhouse gas abatement.

In addition to these monetarized benefits (of avoided damages), climate and air pollution policies could also boost technological developments – and thus lead to EU leadership in some areas. Efficient EU policies could include strict emission standards as to promote clean innovative options and create a market for cleaner products that meet the long term environmental targets.

Many of the technology options for greenhouse gas emission reduction need to be further developed in the next decades. This leads to costs, but it may also lead to opportunities for enhancing the EU's international competitiveness. While picking winners is hard, the EU could focus its technology policy on breakthrough options with early mover advantage and major export potential. Examples of these options are gasification technology (which would create more fuel flexibility, can easily be adapted to carbon capture and storage, creates very low air pollution and is easy changeable to further advanced energy systems) and advanced car technology (like biofuel-hybrid cars).

1. Introduction[1]

There are concerns about Europe's economic performance in a globalizing world. In response the EU has adopted its Lisbon Agenda for becoming the most competitive economic region in the world. Another concern is increased oil and gas prices due to geo-political instability that may endanger its economic performance. This asks for sound energy policy. Such policy should be linked to environmental issues such as climate change and air quality. The recent Green Paper on a European strategy for sustainable, competitive and secure energy by the European Commission (EC, 2006) has put energy policy high on the EU agenda.

This note explores the linkages between energy policy options and environment with an emphasis on climate change and air pollution. It looks at the environmental impacts of additional energy options in comparison to a baseline encompassing current policies. More specifically this short report first presents a quick scan of various single technology options, followed by a description of the impacts that integrated emission reduction strategies would have. Costs of emission reduction options are compared with the impacts on greenhouse gas emissions (GHG), local air pollution, and import dependency for gas and oil.

2. Policy context and issues at stake

Energy security
Energy security is a major political concern. An increasing part the EU's energy needs will have to be covered by imports. Particularly, for the supply of oil and natural gas, the EU becomes more dependent on a small number of countries, some threatened by political instability. At the same time, high economic growth in developing countries like China and India is expected to boost world energy demand further. As such, energy markets could become increasingly tight. Four types of risks can be distinguished (CPB, 2003):

- increasing market power of oil and gas exporters;
- increasing dependency of gas supply from Russia and the Middle East;
- insufficient investments in production capacity;
- insufficient investments in power and natural gas networks.

These risks might lead to high and volatile energy prices that could have major economic impacts.

This concern about increased risks and vulnerability should be kept in perspective (IMF, 2005)[2]. Whether increased import dependency poses a real problem depends crucially on the geopolitical situation. In a cooperative, market oriented world increased energy dependency does not necessarily represent a serious liability. However, in a less cooperative political context, the situation may become very different as risks of temporary or longer cuts in supply will be exacerbated.

[1] We gratefully acknowledge comments made on a draft version of this paper by Joop Oude Lohuis, Rob Maas, Jos Nootenboom, Michel den Elzen, Bart Wesselink, Wouter de Ridder, Jacco Farla, and Ton van Dril (Energie Centrum Nederland).

[2] The recent price increase is small compared to the two oil price shocks in the 1970s, and in real terms the prices are well below historical peaks. Moreover, the oil intensity of consumption and production, particularly for advanced economies, is now significantly lower than in the 1970s, but also have started to use much more natural gas and nuclear. Finally, the durability of the price increase is uncertain, given uncertainties about medium- and long-term supply and demand behavior. The impact of the higher oil price on the global economy is likely to be limited. It has been estimated that a $10 rise in the oil price, if sustained for a year, cuts GDP in OECD countries by 0.4% (IEA, 2004). The adverse effect can be four times worse in very poor developing countries. Structural effects may be more severe. Especially the transport sector is oil dependent.

No clear EU targets for energy security exist. The Green Paper (EC, 2006) sets out a number of directions envisaged as components of an overall energy policy framework:
- reduction of demand;
- diversifying the EU's energy mix with greater use of competitive indigenous, and renewable energy;
- diversification of sources and routes of supply of imported energy;
- streamlining internal energy markets;
- better equipping the EU to cope with emergencies.

Competitiveness
The Lisbon Strategy is an agenda for social-economic change, aimed at creating a dynamic knowledge-based economy with strong growth (3% per year in the EU) and more and better jobs (70% employment by 2010). Although the Lisbon Strategy is part of a broader European sustainable development strategy, the focus is on competitiveness, jobs and growth, and much less on social or environmental issues (de Ridder and Wesselink, 2006).

Environmental policies come at a cost and there is fear that EU unilateral policies may affect the EU's competitiveness and lead to reallocation of industries. Empirically, there is little evidence that stringent environmental standards have hampered economic performance, or that they have been a decisive factor for (re)allocating of industries (ECOTEC et al, 2001; Bollen et al., 2002). Environmental regulation is but one of the many factors that businesses take into account when choosing among several options of location. The idea that environmental policy deteriorates competitiveness is often based on a static view on competitiveness in which technology is considered exogenous. From a dynamic perspective, environmental policy may induce product and process innovations that may even enhance competitiveness. EU countries with stringent environmental policies, like Finland and Sweden, have proved to be able to be very competitive, particularly due to technological innovation.

Macro-economic analyses of the impacts of, for example, climate policies show that impacts can be limited, provided that the coalition of countries is sufficiently large (including some major developing countries) and flexibility mechanisms - like emissions trading and the Clean Development Mechanism (CDM)- are being used (Bollen et al., 2005).

Climate Change
Climate change poses one of the most challenging environmental concerns to the world. On the basis of recent scientific findings[3] on the risks of climate change the EU Spring Council in 2005 re-stated its long-term goal of limiting global temperature increase to 2˚ C above pre-industrial levels. In view of the global greenhouse gas emission reductions required and given the differentiated responsibilities and capabilities of developed and developing countries, the EU environment council concluded that developed countries should consider emission reduction targets in the order of 15-30% by 2020 and possibly 60-80% by 2050 (EU, 2005)[4].

The major part of the projected increase of greenhouse gas emissions takes place in developing countries, even though per capita levels will remain much lower. Abatement measures in developed countries only will not be effective and will raise competitiveness concerns. Within the UNFCCC developing countries and also some industrialized countries are still very reluctant to take on new commitments as these could hamper their economic development. Outside the UNFCCC framework discussions on climate policy focus on clean

[3] Like those presented at the UK Exeter symposium on dangerous climate change last year (Schellnhuber et al.,2006).
[4] Research indicates that for a reasonable chance of meeting the EU target, global emissions need to be stabilized before 2020 and reduced by 30-50% by the middle of the century (den Elzen and Meinshausen, 2005, 2006).

development and technological cooperation (G8, Asian Pacific Partnership). There is a tendency to focus on other strategies than targets and timetables, in particular clean development and technological cooperation. Meanwhile, various parties to the Kyoto Protocol, including Japan, Canada, but also various EU member states have great difficulty in implementing policies for reversing emission trends (UNFCCC, 2005; EEA, 2005). Thus, the EU needs to consider various strategies for meeting its policy objectives. Such strategies may include more focus on enhancing technological development and dissemination and integrating climate policies with other policy objectives as analysed in this paper.

Local Air Pollution
Since the 1970s Air pollution has been recognized as a problem. From the early '80s on, national and increasingly European regulations, starting with various protocols of the UN-ECE, have resulted in declining air pollutant emissions and air quality improved. Nonetheless, recent research suggests that in the EU25 370.000 people are still dying from exposure to air pollution (EU, 2005) annually. In 1999, the European Union signed the multi-pollutant and multi-effect "Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone". This protocol was translated into the EU-directive on national emission ceilings (NEC) for 2010 for four pollutants: sulphur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic components (VOCs) and ammonia (NH_3). Both the Gothenburg protocol and the NEC-directive were negotiated on the basis of scientific assessments of pollution impacts and abatement options with the RAINS model (see Amann et al., 2004), aiming to mitigate the significant negative impacts of air pollution on health and the environment. In addition the EU came forward with supporting directives, ranging from regulating various emission sources (e.g. traffic – EURO standards; combustion plants – Large Combustion Plant directive; industry- Integrated Pollution Prevention and Control) to air quality standards directives. Most recently the Commission published the CAFÉ thematic strategy on air quality (EU, 2005).

3. Policy options per issue

Energy security
To cope with decreased energy security, policy interventions should aim to prevent disturbances; reduce the vulnerability of the economy and mitigate the adverse effects of these disturbances. Options include: investing in bilateral relations with energy suppliers; energy saving; decreasing oil and gas intensities; and investing in strategic oil and gas reserves. Options to diversify power supply involve the enhanced use of coal, nuclear, and renewables. In the transport sector supply can be diversified by the use of biofuels to replace oil or the use of electric traction (e.g. public transport). In addition, strategic reserves could be increased to reduce vulnerability for short-term disruptions of supply in combination with an reinforced internal energy infrastructure to secure energy supply.

Sound policy asks for carefully comparing the costs and benefits of insecurity reduction. Investing in higher cost fuels, building strategic reserves, or more trans-European energy infrastructure to displace risky imports, incurs costs. The benefits are the avoided costs of supply interruptions, together with any environmental benefits that may ensue.
From an economic point of view, therefore, it could be often wiser to accept consequences of supply disruptions than to pursue security of supply at any cost[5].

Competitiveness
The Lisbon strategy on growth and employment focuses on five objectives: employment, human capital, research and development (R&D), the internal market for services, and the

[5] The general picture following from case studies (CPB, 2003) is that measures aimed at increased security of supply measures are often not beneficial to welfare: benefits of policy measures do generally not outweigh their costs.

administrative burden. According to a study by the CPB Netherlands Bureau for Economic Policy Analysis, Europe's Gross Domestic Product could increase by 12 to 23% and employment by about 11% by 2010 if Europe actually reached the goals it has set (Gelauff and Lejour, 2006). However, the study did not assess the environmental implications nor the role of the promotion of technological innovation through environmental policies. To promote sustainable development R&D subsidies could be targeted more towards specific technologies, while announcing stricter regulation in the future could increase R&D expenditures.

Climate change

There is a wide range of technological options for limiting and eventually reducing global greenhouse gas emissions. Main reduction options on the short term include energy saving, fuel switch, and non-CO_2 reductions; on the long term. major supply side changes to low-carbon and carbon-free options are needed. This includes the large-scale use of biofuels, carbon capture and sequestration, nuclear and renewables. Leaving out options will significantly raise costs. However, many long-term options are still not yet commercially available and require significant cost reductions. The central issue is therefore how to make a transition to low-carbon energy systems. This transition requires the implementation of both a technological push and a market pull. Technology development can be pushed in various ways. One way is to increase R&D expenditures in energy technologies, which have gone down over the last decades. Picking winning technologies is difficult, though, and only boosting R&D investments does not provide certainty regarding environmental effectiveness. Moreover, cost reductions require learning by doing. Therefore, apart from a technology push there is a need for creating (niche) markets, either by regulation (technology performance standards or minimum share requirements), or by market instruments (emissions trading or taxation). The Kyoto Protocol approach has focused on market instruments (cap and trade), little on technology oriented policies (R&D, technology standards). These latter policies provide alternative options for a push and pull strategy for achieving a transition to low-carbon societies.

Local Air Pollution

Most of the current options to improve local air quality have a so called end-of-pipe character (see IIASA website, Rains model), but there could be a large potential for options to improve the fuel quality, and of climate policy options such as fuel shift and energy savings that lead to less air pollution. The most promising energy options are those that reduce emissions of existing coal-fired powerplants and diesel-engines. Existing air pollution legislation control costs are expected to rise from 23 billion Euros a year in the EU25 in the year 2000 to € 40 billion in 2010 and € 54 billion in 2020. If the Strategy on Air Quality is adopted these costs will rise with another 7 billion Euro by 2020. Nevertheless, benefits will still outweigh costs (Folkert, 2005). Ozone and Particulate Matter seem to have the most damaging and persistent impacts on health and the environment. Health is probably the most pertinent problem, because damages are incurred as a result of premature deaths from chronic exposure, and monetized benefits of avoided damage from particulate matter are already larger than the costs involved in reducing its' emissions[6].

---

[6] The premature deaths associated with particulate matter emissions are mostly the result of the fraction of particulates with a diameter smaller than 2.5 μm. In the remainder of this note, the problem will be referred to as the local air pollution, although European emission reductions contribute to concentration reductions throughout the region, and hence lower damage costs from air pollution. Estimates for the number of life years lost per person vary between a few years up to more than 10.

4. Impacts of single energy technologies

Table 1 gives an overview of various energy technologies and emission reduction options and provides the results of a quick scan of their implications for Europe's energy security, competitiveness, and environment, notably climate change and air pollution. Given the complexity of the issues addressed, for this assessment simplifications in indicator choice had to be made. Thus for competitiveness two indicators were used; short-term investment cost and innovation potential to reflect both the static short-term as well as the longer-term dynamic dimension of competitiveness. The scores in Table 1 are relative to baseline developments[7].

The results show that there are many technologies that have both a positive impact on energy security and abating greenhouse gas emissions and air pollutions. Examples are various energy saving options, public transport, nuclear and renewables. There are however some important drawbacks. Some technologies are still expensive, like Photo-Voltaic cells, coal and biomass gasification. Others have considerable other environmental impacts such as radioactive waste in the case of nuclear, and land-use claims and implications for biodiversity and landscape in the case of wind and biofuels.

There are also technologies that have an antagonistic impact on meeting different goals. Examples are the replacement of gas by coal (energy security versus greenhouse gas emissions); the production of diesel from coal (energy security versus greenhouse gas emissions and air quality), the use of conventional biomass such as first generation biofuels or co-firing (greenhouse gas emissions and energy security versus air quality). Of some technologies, like hydrogen, the impacts can vary as they depend on the energy source used (e.g. hydrogen production can be based on coal, nuclear or renewables).

From the technologies with synergetic impacts, some seem to provide particular good opportunities for innovation by European industries. Such options include (multi-fuel) gasification technology, CHP systems, solar and nuclear technology in the power sector, advanced car technology (e.g. biofuel hybrids) and public transport (e.g. high speed trains), and CO_2-capture and storage as the EU has substantial storage capacity and concentrated CO_2-emission sources (IPCC, 2005).

Options and policies

Any of the technological options discussed here can be supported by a range of policies – of which some are more effective and/or efficient than others. Policy instruments available are setting standards or requirements, emission trading, taxes and charges, subsidies and tax exemptions, public procurement policies, infrastructure investments, education and public communication.

In climate policy, the EU has chosen emissions trading as a main instrument to control greenhouse gas emissions efficiently. In air pollution policies standards are the main instrument. R&D subsidies are important instruments to enhance technological innovation.

---

[7] Table 1 shows, for example, that the use of CHP leads to more energy efficiency. However, as, gas-based CHP can replace either coal or natural-gas based conventional technology, the impact on fuel security is unclear. But it will have a positive impact on the level of GHG emissions, as the primary energy requirement drops. The air quality will be improved since the background concentrations levels of Particulate Matter will be lowered by 10 percent. There are no other environmental problems associated with this option. Finally the costs can turn out to be low or even zero at higher future baseline energy prices (gas), as CHP significantly reduces inputs of production.

Table 1: Impacts of technological options on various policy objectives

	Energy Security	Environment			Competitiveness		Remarks
	Energy import dependency	Geenhouse gas emission reduction	Air quality	Other Environ ment	Costs*	EU-Innovation	
Efficiency							
Energy Efficiency	+	+	0/+	0/+	–/0	+	Also combined heat and power
Advanced cars	+	+	0/+	0/+	– –	+	Hybrid cars (e.g. (bio)diesel based), Fuel cell / electric car
Nuclear solar and wind							
Nuclear	0/+	+	+	–	0/-	0/+	Waste and proliferation externality
Stimulate (small) hydropower	+	+	+	-/0	0	0	Limited physical potential
Hydrogen	0/+	–/+	+	–/+	– –	+	Fuel cell technology various generation options
Wind	+	+	+	–	–	0/+	Limited economic potential
Geo thermal	+	+	+	–/0	0/–	0	Limited potential
Solar thermal	+	+	0/+	0	–	0	As substitute for gas space heating
PV energy	0/+	+	+	0	– –	+	Very expensive
Bio energy							
Oil seeds	+	+	–	–/0	–	0	1st generation biodiesel (replaces oil)
Transport (Gas to Liquid)	+	+	+	–/0	–	+	2nd generation biodiesel
Ethanol	+	+	0	–/0	0	0	Imported replacement for gasoline
Carbon Capture and Storage							
Solids gasification+CO_2 capture	0/+	+	+	–	–	+	
Gas + CO_2 capture	0/-	+	0	0	–	+	More gas use due to energy penalty
Fuel Switch							
Gasification	0/+	+	+	–/0	–	+	Electric power; replaces coal
Co-firing	0/+	+	–	–/0	–	0	Electric power (replaces coal)
Gas for Coal	–	+	+	+	–/0	0	
Coal to liquid (diesel)	+	–	–	–	-/0	+	
Multifuel Gasification	+	–/+	+	–/0	–	+	Coal, gas, and biomass; gas cleaning (waste management)
Other							
Public transport, and rail or waterway transport (goods)	0/+	+	+	0/+	–	0/+	Also fast train technology
Clean Coal (air filtering)	0/+	–	0/+	–	0/+	0	No PM emissions
Emission control sea ships	–/0	0/+	+	0	–	+	
Emission controls	0	0/–	+	0	– –	+	filters and catalytic cleaning
Strategic Reserves (Oil and Gas)	+	0	0	–	–	0	less short term shortages
Non-CO2							
Reducing non CO2 Greenhouse gas emissions	0	+	+	0	–	0/+	CH4, N2O, F-gases

Legend: impacts are + = positive; 0 = insignificant; – = negative; – – = very negative (only used for indicated (additional) costs. +/- = from positive to negative depending on technology choices.
* Costs indicate the percentage change of discounted expenditures to the energy system (investments and variable costs of end-use energy services); - indicates negative impact on GDP growth

Technological innovation is needed for a transition to a low carbon society that at the same time meets air pollution targets, enhances energy supply security and minimizes other environmental affects. This requires policies that provide long-term certainty about market development. Economic instruments, like emissions trading, do not provide such sufficient long-term certainty, nor will they always choose options that minimize other environmental effects. Here, as in air policies, long-term standard setting at the level of processes and products is probably more effective (e.g. the Californian experience with the zero emission car requirement) and more able to account for avoiding other unintended effects. As picking winning technologies is difficult, these standards should leave the choice of specific technologies to the market. As a complement to this market pull policies, the EU could provide a technology push by enhancing general support for R&D investments. Tax exemptions and investments in specific technology programs may be useful instruments here. While picking winners is hard, the EU could focus its technology policy on breakthrough options with early mover advantage, major export potential, and more resource flexibility. Examples of such technologies are gasification technology (which allows for very low air pollution levels, is easily adaptable to carbon capture and storage, and changes to more advanced energy systems) and advanced car technology, like hybrid cars.

5. Policy strategies and synergies

How serious are the issues raised in the previous sections in quantitative terms? The IEA's 2004 World Energy Outlook (IEA, 2004) indicates that under 'business-as-usual' assumptions, global energy consumption is likely to grow by almost 60% between 2002 and 2030, while fossil fuels will continue to dominate global energy use (accounting for 80% of the global energy use in 2030.) The IEA also indicates that in this baseline, energy security risks are likely to grow as result of increasing concentration of oil and natural gas supply. Moreover, CO_2 emissions are likely to grow by more than 60% globally.

The Netherlands Environmental Assessment Agency explored the types of measures and combination of energy options that would result in significant reductions of greenhouse gas emissions by 2030 (Van Vuuren et al., 2006)[8]. The study also looked into the impacts of climate policy measures on climate, local air pollution and energy security and estimated the costs of these strategies[9]. These GHG reduction strategies aim at long run stabilisation of greenhouse gas concentrations at three different levels:

- Modest policy scenario (global concentrations increase to 650 ppm CO_2-eq);
- Moderate reduction scenario (global concentrations increase to 550 ppm CO_2-eq);
- Stringent reduction scenario (global concentrations increase to 450 ppm CO_2-eq);[10]

The first strategy is very comparable with the IEA's 'no-regret' policy scenario. With this scenario the IEA showed that it is possible to identify alternative policies that could achieve synergies between climate change policies and energy security policies at very limited costs. The measures included in this scenario would reduce global oil and natural gas demand by about 10% and, at the same time, it would reduce global CO_2 emissions by 16% compared to

---

[8] The current analysis is carried out at the level of global regions (including the EU). Country level information can be obtained from more detailed models such as POLES, GAINS and PRIMES.

[9] Costs are measured as higher annual expenditures on energy (from increased investments and operation and maintenance costs) compared to the baseline, when adding a carbon price (from global emissions trading) on baseline energy prices. For comparison, currently total costs for environmental policies in EU countries are generally around 1-2% of GDP while the total energy system costs are around 6-8% of GDP.

[10] The EU commitment under these reduction strategies depends on the differentiation of future commitments. Den Elzen et al. (2006) shows that under a multistage regime the 550 ppm could lead to an EU reduction commitment of around 25% compared to 1990; the 650 ppm regime could lead to an reduction commitment of around 45% compared to 1990.

the 'business as usual' scenario. It should be noted, however, that IEA's 'no-regret' policy is not consistent with the EU climate policy targets: it neither reduces 2020 emissions by 15-30% compared to 1990 levels nor does it limit global temperature increase to 2°C above the pre-industrial level. The second and third reduction strategies were developed to analyze strategies that have a much higher probability of meeting the 2°C target (i.e. around 20% and 50%, respectively).

Figure 1: Contribution of various measures in the EU in 2030 to reduce greenhouse gas emissions for the 3 reduction strategies discussed in this paper (CCS = Carbon capture and storage; fuel switch encompasses substitution from high-carbon to lower-carbon fossil fuels; non-CO_2 encompasses reduction of CH_4, N_2O, HFCs, PFCs and SF_6). Source: Van Vuuren et al., 2006; Den Elzen et al. 2006.

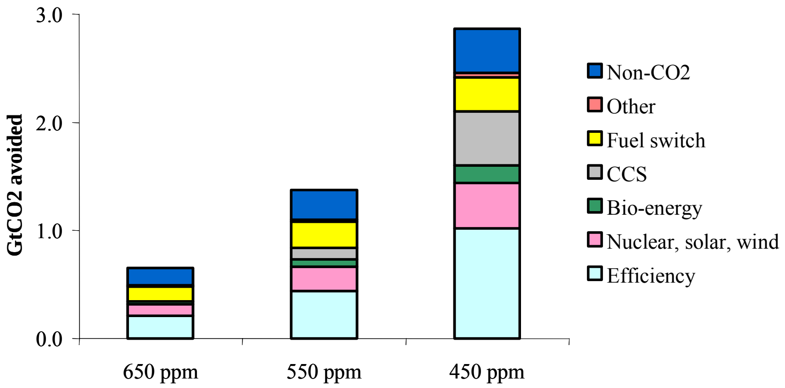
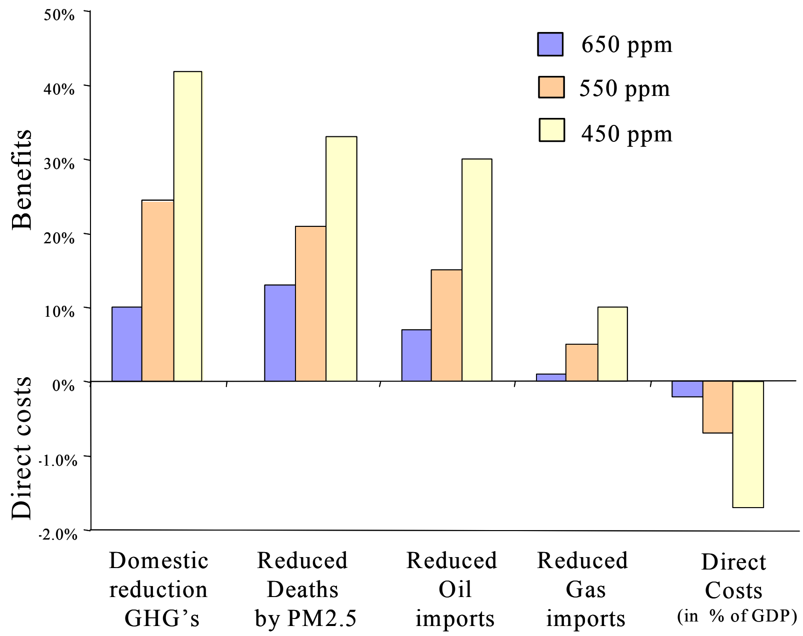


Figure 1 shows the contribution of technological options to greenhouse gas emission reductions of the three strategies for 2030. Reductions vary from about 0.6 Gt CO_2-eq. to 3 Gt CO_2-eq. Within the total portfolio of measures to reach these reductions, increased energy efficiency plays a particularly important role. More stringent reduction targets also call increasingly for CO_2 carbon capture and storage (CCS), though the latter can be substituted at limited additional costs against other electric power options (nuclear power and renewables). In 2030, other options include reductions of non-CO_2 gasses and fuel switch (using natural gas instead of coal). It should be noted that beyond 2030, the contribution of fuel switch will diminish; while the contribution of non-CO_2 gasses will not increase further. In contrast, the contribution of bio-energy, which is still relatively small in 2030 (in all these reduction strategies), is projected to substantially increase afterwards.

The EU abatement costs are estimated to be in the order of 0.7% of GDP in 2030 in 550 ppm case and 1.7% of GDP for the 450 ppm case. In both cases, costs will further increase after 2030 and peak around 2050. The study assumes full global emission trading. Total macro-economic consequences crucially depend on the way climate policy is implemented: i.e. the number of countries participating in future climate regimes. Bollen et al. (2005) estimated that for 2020, the macro economic costs of stabilisation to 450 ppm could be around 0.5% of national income. However, if only the EU-25 implements stringent reduction measures, the macro-economic costs in 2020 could increase to 2.3% of national income.

The reduction strategies do show the possible synergies between climate policies, air pollution control and reduced security risks. For the 550 ppm case European imports in 2030 are reduced by 15% for oil and 5% for natural gas. For the 450 ppm case these numbers are 30% and 10%, respectively. These reduced fossil fuel imports are partly replaced by additional production (and imports) of bio-energy. The changes of energy supply induced by climate policies also reduce emissions of air pollutants. Here, the focus is on particulate matter (PM). In the baseline, emissions are likely to be reduced compared to 2000 – but will not meet the ceilings proposed in the Thematic Strategy on Air Polution, despite implementation of the abatement technologies that are part of the current legislation. The 550 ppm and 450 ppm scenarios could reduce PM emissions by 25 and 35%. In fact, these reductions would by themselves be enough to meet the Thematic Strategy targets around 2030.

Figure 2: Benefits and Costs for energy security, climate and air quality in relation to abatement costs of the three GHG reduction strategies in 2030 scenario's (percentage difference from baseline). Source: Based on Van Vuuren et al., 2006; Den Elzen et al., 2006., and own calculations



Note: Selected indicators for the policy issues: climate change (domestic reduction of GHG's), air pollution (reduced deaths by $PM_{2.5}$), energy security (reduced oil & gas imports), and competitiveness (direct costs) in the different reduction strategies. Benefits are reported relative to baseline. BL = indicates the score for the baseline. 100% indicates complete reduction to zero. Costs are plotted in terms of abatement costs as % of GDP. Current costs for environmental policies in the EU are about 2% of GDP. Expenditures on energy are about 6-8%. Each indicator is represented in its own units.

The results of the analysis are summarized for 2030 in Figure 2. There is significant potential for synergies between climate policy, air pollution control and energy security. The tighter the climate policies, the higher the benefits for the other policies areas (import of fuels and air pollution) will be. At the same time, costs of climate policy also increase. The health benefits of the stringent climate change policy scenario can also be quantified. In the most stringent climate policy scenario, the welfare benefits due to less air pollution may already offset the direct costs of climate policy since in monetary terms the impacts of reduced deaths in the EU25 (125.000/year) and morbidity (e.g. 88.000 fewer cases of chronic bronchitis per year and 100 million fewer restricted activity days) are estimated at 0.9 to 2.8 percent of European Union's GDP. This point is also confirmed by a combined Cost-Benefit Analysis on climate change and air pollution (see Bollen et al., 2006). The welfare effects of climate policy seem to be positive, even when the long term benefits of avoided climate impacts are not taken into account. An overview of literature on risks of climate change as a function of global mean temperature increase can be found in IPCC's Third Assessment Report and a recent publication by MNP (2005).

References

Amann, M., Cofala, J., Heyes, C., Klimont, Z., Mechler, R., Posch, M., and Schöpp, W., The Regional Air Pollution Information and Simulation (RAINS) model, February 2004, Interim Report, International Institute for Applied Systems Analysis, Laxenburg, Austria. Also available on the web, http://www.iiasa.ac.at/rains/review/review-full.pdf.

Amann M., Imrich Bertok, Rafal Cabala, Janusz Cofala, Chris Heyes, Frantisek Gyarfas, Zbigniew Klimont, Wolfgang Schöpp, Fabian Wagner (2005). A final set of scenarios for the Clean Air For Europe

Bollen, J.C, Groot, H.L.G. de, Manders, T., Tang, P.J.G., Vollenbergh, H.R.J., Withagen, C.A.(2002). Klimaatbeleid en Europese concurrentieposities, CPB, The Haque.

Bollen, JC, Manders, AJG, and Veenendaal, PJJ (2005), Caps and Fences, RIVM, Bilthoven.

Bollen, J.C., Brink, C., Eerens, H., and van der Zwaan, B. (2006), Local Air Pollution and Global Climate Change: A Combined Cost-Benefit Analysis, to be submitted.

CPB (2003), *Energy Policies and Risks on Energy Markets, A cost-benefit analysis*, CPB Bijzondere Publicatie 51, The Hague. http://www.cpb.nl/nl/pub/cpbreeksen/bijzonder/51/bijz51.pdf

den Elzen, M.G.J. and M. Meinshausen, Meeting the EU 2°C climate target: global and regional emission implications, MNP-report 728001031 (www.mnp.nl/en), Netherlands Environmental Assessment Agency (MNP), Bilthoven, the Netherlands, 2005.

den Elzen, M.G.J. and M. Meinshausen, Multi-gas emission pathways for meeting the EU 2°C climate target, in: *Avoiding Dangerous Climate Change*, eds. H.J. Schellnhuber, W. Cramer, N. Nakicenovic, T. Wigley, and G. Yohe Cambridge University Press, Cambridge, UK, 2006.

den Elzen, M.G.J. , Lucas, P.L. and van Vuuren, D.P (2006). Regional abatement action and costs under allocation schemes for emission allowances for achieving low CO2-equivalent concentrations, Climatic Change (submitted)

EC, 2006. A European strategy for Sustainable, competitive and secure energy. Green paper European Commission. COM(2006) 105 final.

ECOTEC research & consulting, CESAM, CLM, University of Gothenburg, UCD, IEEP (2001). Study on the economic and Environmental Implications of the Use of Environmental Taxes and Charges in the European Union and its Menber States, Final Report – Executive Summary, Brussels/Birmingham, Belgium/UK.

EU (2000), *Towards a European strategy for the security of energy supply* EU Green Paper (COM(2000) 769 final of 29 November 2000).

EU, 2001a, Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants L 309/22, Brussel, 2001

EU, 2001b, Directive 2001/80/EC Of The European Parliament And Of The Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants, L 309/1, Brussel, 2001

EU, 2005, Communication From The Commission To The Council And The European Parliament;Thematic Strategy on air pollution Brussels, 21.9.2005, COM(2005) 446 final (CAFE) programme. CAFE Report #6, International Institute for Applied Systems Analysis (IIASA), http://www.iiasa.ac.at/rains/CAFE_files/CAFE-D3.pdf

Folkert, R.J.M. 2005. Consequences for the Netherlands of the EU thematic strategy on air pollution, MNP report 500034002, MNP, Bilthoven.

Gelauff, G.M.M. and Lejour, A.M. 2006. Five Lisbon highlights – Economic impacts of reaching these targets, Netherlands Bureauu for Economic Policy Analyses (CPB), The Hague.

Holland, M., Watkiss, P, Pye, S, Oliveira, A, and Van Regemorter, D, (2005), Cost-benefit analysis of policy option scenarios for the Clean Air for Europe Programme (CAFE), European Commission DG Environment, reference number AEAT/ ED48763001/ CBA-CAFE ABC scenarios, Brussels, Belgium.

Holland, M., Hunt, A., Hurley, F., Navrud, S., and Watkiss P. (2004), Final Methodology Paper (Volume 1) for the Clean Air for Europe Programme (CAFE), European Commission DG Environment, reference number AEAT/ED51014/ Methodology Issue 4, Brussels, Belgium.

IMF (2005), *Oil Market Developments and Issues*., www.imf.org/external/np/pp/eng/2005/030105.pdf

IPCC, 2005. Special Report on Carbon Capture and Storage, Cambridge University Press, UK.

MNP (2005). Limits to warming. In search of targets for global climate change, Netherlands Environmental Assessment Agency (MNP), Netherlands (www.mnp.nl/en), 2005, Bilthoven.

De Ridder, W., and Wesselink, L.G., EU SDS: ingredients for the 2006 revision, MNP-report 500096001, Netherlands Environmental Assessment Agency (MNP), Bilthoven, the Netherlands, 2005.

Schellnhuber, H. J., W. Cramer, N. Nakicenovic, T. Wigley, and G. Yohe Cambridge University Press, Cambridge, UK, 2006.

van Vuuren, D.P., M.G.J. den Elzen, B. Eickhout, P.L. Lucas, B.J. Strengers, and B. Ruijven, Stabilising greenhouse gas concentrations. Assessment of different strategies and costs using an integrated assessment framework., Climatic Change (submitted) (2006).