**Abstract** – This paper presents the external costs of electricity due to climate change and security of energy supply derived during EU Framework 6 project “Cases”. The cost of greenhouse gases emissions is an important component of the total external cost of electricity production. In the framework of the CASES project, two approaches were followed to assess global warming. With the first methodology, the quantifiable marginal damage costs of climate change were estimated, while with the second one the marginal avoidance costs of GHG emissions was based on Meta analysis. The paper will focus on the power sector therefore for external cost of energy security the Value of Lost Load (VOLL) will be applied. The aggregate value of security of electricity supply can be expressed by multiplying the probability of the intensity, frequency and duration of supply disruptions, i.e. expectation value of the amount of electricity not served by VOLL. The paper discusses external energy cost evaluation methodologies, results of external costs of climate change and energy security assessments provided in CASES project and develop recommendations for the integration of these external costs in decision making in energy sector.

**Keywords** – Climate change, energy security, external cost.

1. **INTRODUCTION**

The costs of electricity generation and distribution are the most important criteria shaping decisions within the electricity system. However, the influence on the environment and human health due to climate change and air pollution should also be adequately taken into account [1]. This includes impacts from the whole life cycle of electricity supply including operation of a power plant. Thus results from an LCI (Life Cycle Inventory) assessment have to be used [2]. To be able to compare the different impacts of different technologies and systems, the impacts (risks, damage) have to be transformed in a monetary unit. The ‘ExternE’ methodology is used to weight the mostly site depended, impacts according to the preferences of the society. As result damage costs, which are mostly external costs are obtained [3].

The sum of the ‘private’ costs and external costs give social costs. For example, the social costs of an innovative renewable technology may be competitive or even smaller than the social costs of a conventional fossil fuelled technology, even if private costs are higher. The technological progress offers solutions for the challenge of a more sustainable energy supply. The comparison of internal and external cost can help to identify the technologies mix to be aspired.

Therefore, an external cost arises when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group. Thus, a power station that generates emissions of SO₂, NOx particulates etc. causing damage to building materials, biodiversity or human health, imposes an external cost. This is because the impact on the owners of the buildings, crops or on those who suffer damage to their health is not taken into account by the generator of the electricity when deciding on the activities causing the damage. Therefore the environmental costs are “external” because, although they are real costs to these members of society, the owner of the power station is not taking them into account when making decisions [4].

During the EU Framework 6 programme under priority Sustainable energy systems CAES project was financed. The aim of the project was to evaluate external and private cost of electricity generation in EU-27 and other countries seeking to provide reliable data for electricity system development scenarios in case then external costs are integrated through all the chain of electricity supply system.

Energy and climate change are on top of the agenda of the European Union (EU) today. Based on the European Commission’s energy policy package entitled “Energy Policy for Europe” [5], which was accompanied by a number of sectoral policies to implement the overall strategy, the Member States adopted an Energy Policy for Europe (EPE) which pursues three objectives: increasing security of supply; ensuring the competitiveness of European economies and the availability of affordable energy, and promoting environmental sustainability and combating climate change. External cost of climate change and security of supply can be a valuable tool for shaping energy policies and decision making in energy sector [6]. During CASES project external costs of climate change and energy security were evaluated [6]–[8].

The aim of the article is to analyse external costs of energy security and climate change:
• Short overview of methodologies applied in CASES project;
• Analysis of external costs of GHG emissions;
• Analysis of external costs of energy security;
• Analysis of EU energy policy priorities and interactions between climate change mitigation and energy security targets;
• Development of policy recommendations for the integration of external costs of climate change and energy security in decision making.

2. METHODOLOGIES APPLIED FOR EXTERNAL COSTS EVALUATION

In 1991 European Commission together with the US Department of Energy launched a joint research project to assess the environmental externalities of energy use. The design of the project reflected the ambitious objectives as well as the multi-disciplinary nature of the task. A large number of researchers of different disciplines joined this attempt. The need for modelling the full ‘impact pathway’ of pollutants from the power plant stack through their interactions with the environment to a physical measure of impact, and where possible, a monetary valuation of resulting welfare losses forced the participating scientists to develop a common understanding and appropriate interfaces between the relevant scientific areas. After the first phase of the project, which ran over 4 years, an operational accounting framework for the assessment of external costs of energy technologies—named ExternE in Europe—was delivered [3]. More than 50 teams from 15 countries in Europe participated in follow-up activities on the improvement, dissemination, and application of the ExternE results [4]. The ExternE label became a recognised ‘brand’, the scientific quality of the work was well accepted on the international level, national and international organisations got used to referring to ExternE numbers as a standard source for external cost data, and also industry expressed increasing interest in ExternE result.

Seven major types of damages have been assessed within ExternE methodology. The main categories are human health (fatal and non-fatal effects), effects on crops and materials. The impact pathway approach - and coming along with this approach, the EcoSense model, an integrated software tool for environmental impact pathway assessment - was developed within the ExternE project series and represents its core [9].

Impact pathway assessment is a bottom-up approach in which environmental benefits and costs are estimated by following the pathway from source emissions via quality changes of air, soil and water to physical impacts, before being expressed in monetary benefits and costs. The use of such a detailed bottom-up methodology is necessary, as external costs are highly site-dependent. Two emission scenarios are needed for each calculation, one reference scenario and one case scenario. The background concentration of pollutants in the reference scenario is a significant factor for pollutants with non-linear chemistry or non-linear dose-response functions. The estimated difference in the simulated air quality situation between the case and the reference situation is combined with exposure response functions to derive differences in physical impacts on public health, crops and building material [10].

It is important to note that not only local damages have to be considered – air pollutants are transformed and transported and cause considerable damage hundreds of kilometres away from the source. So local and European wide modelling was performed during ExternE and its extensions [9]. As a next step within the pathway approach, exposure response models are used to derive physical impacts on the basis of these receptor data and concentration levels of air pollutants. In the last step of the pathway approach, the physical impacts are evaluated in monetary terms. According to welfare theory, damages represent welfare losses for individuals. For some of the impacts (crops and materials), market prices can be used to evaluate the damages. However, for non-market goods (especially damages to human health), evaluation is only possible on the basis of the willingness-to-pay or willingness-to-accept approach that is based on individual preferences. To complete the external costs accounting framework for environmental themes (acidification and eutrophication, a complementary approach for the valuation of such impacts based on the standard-price approach is developed and improved. This procedure deviates from the pure welfare economic paradigm followed in ExternE, but it allows estimating damage figures for ecological impacts complementary to the existing data on impacts from the same pollutants on public health, materials and crops (based on damage function approach and welfare based valuation studies). The integration of this methodology and data into the existing external costs framework is an important extension as it also covers impact categories that could otherwise not be addressed properly in ExternE.

3. EXTERNAL COSTS OF CLIMATE CHANGE

At present, more than one hundred estimates of the marginal external costs of the emissions of greenhouse gases (particularly CO₂) have been made. The estimates range from slightly negative (< 0) to over 400 USD per ton CO₂ currently emitted [7]. Tol [11] constructed a probability density function of published estimates. The function is highly skewed to the left, with a long right tail of sparse but high estimates. The mean value of the published estimates is 25 USD per ton of CO₂, but 50% of the studies report costs of less than 4 USD/ton (this is the median value). On the other extreme, 5% of the studies report costs of over 95 USD/ton. If only peer-reviewed studies are taken into account, the mean estimate drops to 12 USD/ton with a standard deviation of 23 USD/ton.

Most researchers agree that the marginal impacts of greenhouse gas emissions increase with the concentration of greenhouse gases in the atmosphere. Therefore, it is commonly assumed that because of the expected
increases in concentration over time, the present value of emissions also increases over time. That is, all else being equal, the present value of emissions in 2010 will be higher than the present value of emissions in the year 2000 [7]. The literature reports annual increases in the marginal costs of CO2 emissions range between 1 and 2 percent [12], [13]. Annual increases of marginal costs for other greenhouse gases may differ in relation to their expected lifetime in the atmosphere. Recently, there has been a flurry of research projects on the 'social cost of carbon' (SCC) in the United Kingdom [14], [15].

The social cost of carbon is the social cost of the emission of one tonne of CO2 at a particular date; hence it is another word for the marginal (social) cost of CO2 emissions. It is measured as the present value of the impacts of one tonne of CO2 over its lifetime in the atmosphere. Large-scale projects included the SCC-project of Watkiss and others [15] and, most recently, the Stern Review [16].

The specific objectives of the SCC project were to review the previous use of the SCC values in policy assessment, and the possible approaches for future assessment, taking into account the factors that influence the values; to undertake expert stakeholder consultation, to obtain their views on how such analysis should be undertaken, and on the uses of SCC estimates in policy assessment in the face of uncertainty; to develop a series of case studies to demonstrate the various approaches for including SCC estimates in policy decision-making; and to make recommendations. Much of the variation in SCC estimates arise from a few key parameters in the choice of decision perspectives, most importantly the discount rate used and the approach to weighting impacts in different regions (called equity weighting). Potential approaches for using the SCC values in policy applications that take risk and uncertainty into account were reviewed, identifying a number of options. There is no single method, model or tool adequately captures all of the uncertainties. The complexity of the nature of a coupled socio-ecological system and the range of decision frameworks that might be employed in using the SCC imply that estimates of the SCC will remain diverse and contentious [7].

Some central estimates of the marginal damage cost of carbon dioxide emissions may be lower than the "illustrative value" of £70/tC (€28/tCO2) that is currently used by the UK government [14].

The Stern Review [16] was another major review of the social costs of carbon. The review assessed the economics of moving to a low carbon economy, focusing on a medium to long term, plus the potential of different approaches to adaptation and lessons for the UK, in the context of climate change goals. From a different perspectives, most importantly the discount rate used and the approach to weighting impacts in different regions (called equity weighting). Potential approaches for using the SCC values in policy applications that take risk and uncertainty into account were reviewed, identifying a number of options. There is no single method, model or tool adequately captures all of the uncertainties. The complexity of the nature of a coupled socio-ecological system and the range of decision frameworks that might be employed in using the SCC imply that estimates of the SCC will remain diverse and contentious [7].

The numerical results of studies into the external costs of greenhouse gas emissions remain speculative, but they can provide insights on signs, orders of magnitude, and patterns of vulnerability. Results are difficult to compare because different studies assume different climate scenarios, make different assumptions about adaptation, use different regional disaggregation and include different impacts.

The Nordau and Boyer [17] estimates, for example, are more negative than others, partly because they factor in the possibility of catastrophic impact. The Mendelsohn et al. [18] and Tol [11] estimates, on the other hand, are driven by optimistic assumptions about adaptive capacity and baseline development trends, which results in mostly beneficial impacts. According to Tol [11], the current generation of aggregate estimates may underestimate the true cost of climate change because they tend to ignore extreme weather events; to underestimate the compounding effect of multiple stresses; and to ignore the costs of transition and learning. However, these studies may also have overlooked positive impacts of climate change and not adequately accounted for how development could reduce impacts of climate change [11].

Tol [11] suggests that our current understanding of (future) adaptive capacity, particularly in developing countries, is still too limited to allow a firm conclusion about the direction of the estimation bias. Estimates of global impact are sensitive to the way figures are aggregated. Because the most severe impacts are expected in developing countries, the more weight is assigned to southern countries, the more severe are aggregate impacts. Using a simple adding of impacts, some studies estimate small net positive impacts at a few degrees of warming, while others estimate small net negative impacts. The need for synthesis and aggregation in the assessment of the costs of climate change poses challenges with respect to the spatial and temporal comparison of impacts. Aggregating impacts requires an understanding of (or assumptions about) the relative importance of impacts in different sectors, in different regions and at different times. The task is simplified if impacts can be expressed in a common metric, but even then aggregation is not possible without value judgments.

Another crucial issue raised by Tol is the need to move from a static analysis to a dynamic
representation of impacts as a function of shifting climate characteristics, adaptation measures and exogenous trends like economic and population growth. Among the few explicitly dynamic analyses are [11], [19]. However, these studies are highly speculative, as the underlying models only provide a very rough reflection of real-world complexities. While some analysts still work with relatively smooth impact functions [17], there is accepted recognition [11] that the climate impact dynamics, i.e. the conjunction of climate change, societal change, impact, and adaptation, is non-linear, and might be quite complex.

The cost of greenhouse gases (GHG) emissions is an important component of the total external cost of electricity production. In the framework of the CASES project two approaches were followed to assess global warming. With the first methodology the quantifiable marginal damage costs for unit of emissions were evaluated for CO₂, CH₄ and N₂O, while with the second one the marginal avoidance costs of GHG emissions were evaluated based on meta analysis.

Since cost data is not site specific, the same values for all EU-27 member states were applied. Data is time specific, hence different values have to be used for the different periods. In Table 1 the damage costs and avoidance costs up to 2010 are presented [8].

As one can see from Table 1 the damage and avoidance costs of CO₂ emissions are in quite good agreement. External costs of other GHG emissions are in quite different range. The highest damage costs are associated with N₂O emissions; however damage costs of N₂O emissions are almost five (5) times higher than avoidance costs. This is related with very high uncertainties in GHG external costs assessments. For external cost of climate change the uncertainty is very high and that the true value could be about five (5) times smaller or larger than the median estimate.

As CASES project for total external costs of electricity supply applied marginal damage costs in Table 2 these costs are presented for the main energy generating technologies including fossil, nuclear and renewable [8].

As one can see from data presented in Table 2 the highest marginal costs of GHG emissions were obtained for lignite and hard coal condensing power plants. Very high marginal damage costs were obtained for straw and woodchips with extraction condensing turbine. The lowest European marginal damage costs are associated with electricity generation at of shore wind mills and other renewable. The nuclear technologies also have quite low marginal damage costs of GHG emissions. The data provided in the Table 2 corresponds to the results of previous studies on external costs of GHG emission assessments.

### Table 1. Marginal costs of GHG emissions in Euro2005 per ton.

<table>
<thead>
<tr>
<th>CO₂</th>
<th>CH₄</th>
<th>N₂O</th>
<th>SF₆</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000-2009</td>
<td>20.66</td>
<td>747.26</td>
<td>27202.90</td>
</tr>
<tr>
<td>2010</td>
<td>19</td>
<td>399</td>
<td>5890</td>
</tr>
</tbody>
</table>

### Table 2. European marginal damage costs of GHG emissions in 2005-2010 per technology, €/kWh.

<table>
<thead>
<tr>
<th>Marginal damage cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear</td>
</tr>
<tr>
<td>Heavy oil condensing power plant</td>
</tr>
<tr>
<td>Light oil gas turbine</td>
</tr>
<tr>
<td>Hard coal condensing power plant</td>
</tr>
<tr>
<td>Hard coal Intg. Gasification Comb. Cycle w/o CO₂ capture</td>
</tr>
<tr>
<td>Lignite condensing power plant</td>
</tr>
<tr>
<td>Lignite IGCC</td>
</tr>
<tr>
<td>Natural gas combined cycle</td>
</tr>
<tr>
<td>Natural gas turbine</td>
</tr>
<tr>
<td>Hydropower run of river &lt;100 MW</td>
</tr>
<tr>
<td>Hydropower run of river &gt;100 MW</td>
</tr>
<tr>
<td>Hydropower run of river &gt;100 MW</td>
</tr>
<tr>
<td>Hydropower dam</td>
</tr>
<tr>
<td>Solar Photovoltaic (PV) roof</td>
</tr>
<tr>
<td>Wind on-shore</td>
</tr>
<tr>
<td>Wind off-shore</td>
</tr>
<tr>
<td>Solar</td>
</tr>
</tbody>
</table>
Solar PV open space 0.4647
Solar thermal parabolic trough 0.419
Natural gas Combined Heat and Power (CHP) with extraction condensing turbine 1.6786
Hard coal CHP with extraction condensing turbine 3.1328
Natural gas combined cycle CHP with backpressure turbine 1.8550
Hard coal CHP with backpressure turbine 3.3858
Straw CHP with extraction condensing turbine 4.9348
Woodchips CHP with an extraction condensing turbine 4.8010
Natural gas fuel cell- Molten Carbonate Fuel Cells (MCFC) 0.9031
Natural gas fuel cell - SOFC 0.7290
Biogas fuel cell- Solid Oxide Fuel Cells (MCFC) 1.4104

4. EXTERNAL COST OF ENERGY SECURITY

The old monopolists used to claim that they guaranteed the security of supply - a statement supported by the experience of decades of service to the public, during which very little disruption was experienced. It is not clear, however, that security of supply was truly guaranteed in the past - as it was in fact never challenged by any major disruption. The old monopolists were in a position to decide unilaterally how much security they intended to provide and did engage in some precautionary investment, thanks to their ability to pass the cost to the final consumer. The security they provided may have been too little or too much. There was no benchmark for measurement. The concern about security of supply in liberalised markets is connected to viewing security as a public good or externality. In liberalised markets, new competitors will be tempted to 'free-ride' on the security provided by the incumbent suppliers and competition may have a negative effect by downplaying security or prioritising cost-cutting. Similar fears have been expressed with regard to other network industries such as airlines, railways and electrical grids [6].

Normally, security is viewed as a matter for governments to look after. This perception holds true for small commercial or household customers, who will not be in a position to judge their security requirements exactly and will need standard contract formulae that set the level of protection to be decided by the regulator. The level of protection does not need to be 100%. Gas in households and small commercial establishments is primarily used for cooking and for ambient- and water-heating. In situations of emergency, all such uses can be reasonably curbed to some degree. It is therefore also reasonable to set the guaranteed level of supplies at an appropriate percentage of 'standard' consumption.

Not all customers need to be protected against supply disruptions. In liberal markets, customers have a choice of whether to assume responsibility for security of supply themselves or to allow the supply company to bear the responsibility and subsequently to pay a risk premium through higher energy prices. The former is typically done by large industrial users, for which (short-term) security might not be an issue, given they can switch fuels. A large industrial user may choose to buy gas from a risky but cheap source, accepting the risk of higher short-term prices from a spot market or mitigating the risk by installing a dual-firing capability or a back-up from another supplier.

The majority of the evidence (modelled and observed) on the macro-economic costs of energy price fluctuations and their impacts on the EU relates to the macroeconomic costs – in terms of lost GDP – from oil prices increases last at least six months. When these costs are apportioned to EU electricity consumption, they are negligible, a mid-point result being 0.000004 per kWh within range of 0.000001-0.000008. The absence of empirical evidence, however, has meant that impacts of short term oil price fluctuations and the potential impacts of equivalent price movements in gas or coal are not quantified [6].

Electricity production and network failures imply costs associated with interruption in power supply. The latter can be expressed in terms of the estimated total damage caused by not delivered electricity divided by the amount of electricity not delivered in kWh. The Value of Lost Load (VOLL) is a monetary expression for the costs associated with inter- or disruptions of electricity supply, as a result of production, transmission and distribution failures. VOLL can be used as a useful variable to quantify the dimensions of energy supply security of a country, region or economic sector.

Table 3 presents the levels of VOLL for developed and developing countries based on analysis of various studies [6].

| Table 3. Levels of VOLL entire economy in 2030, EUR (2007)/kWh. |
|-----------------------------------|-----------------|-----------------|
| Maximum range | 90% CL range |
| Developed countries | 5.0-50.0 | 6.3-31.3 |
| Developing countries | 1.3-12.5 | 2.5-6.3 |

The uncertainty of damage cost is quite high however even in the case of high uncertainties external costs estimates can support decision making in energy sector. In the following chapters EU energy policies will be reviewed and climate change and energy security policies interactions will be revealed based on analysis of EU energy policies and measures.

5. ENERGY POLICY PRIORITIES
In recognition of the risks and challenges to European energy supply, the Heads of State and government of the 27 Member States of the EU at the spring 2007 European Council have committed themselves to a low-carbon energy future [5]. The main aims of Energy Policy for Europe (EPE) are the following:

- Increasing security of supply,
- Ensuring the competitiveness of European economies and the availability of affordable energy, and
- Promoting environmental sustainability and combating climate change.

In the centre of the new energy policy is the EU's commitment to reduce its greenhouse gas (GHG) emissions by at least 20% by 2020 compared with 1990 levels, not least because CO₂ emissions from energy make up 80% of EU GHG emissions. By using less energy and using cleaner, locally produced energy, the EU aims to increase energy security by limiting its growing exposure to increasingly volatile prices for oil and gas, while stimulating competitiveness in the European energy market.

In general terms, the EPE is based on five pillars [6]. First, the EU aims at increasing its energy efficiency by saving 20% of its energy by 2020. This will save about 780 million tones of CO₂ from being emitted into the atmosphere. Second, the share of renewable energy sources in the total energy mix is intended to triple to 20% by 2020, while aiming for a 10% biofuel component in vehicle fuel by 2020. The third pillar focuses on reducing the carbon emissions from hydrocarbons. Of particular importance in this context is the role of coal, which is relatively cheap and available in Europe, but "dirty" in environmental terms as compared to other energy sources. The development of carbon capture and storage (CCS) technologies is thus a crucial factor in securing future energy supplies. The fourth and fifth pillars of the EPE are the EU's carbon market and an open and competitive internal energy market.

A competitive market is expected to increase security of supply by improving the conditions for investment in power plants and transmission networks, which in turn will help avoid interruptions in power or gas supplies. To facilitate its creation, the European Commission has recently published its third legislative package including proposal for a number of measures to increase competition in the EU electricity and gas markets. These include, amongst others, the separation of production and supply from transmission networks ("unbundling"), the facilitation of cross-border energy trade, as well as greater transparency of the markets. These proposals are currently being discussed by the Member States within the Council. In the following paragraphs the main EU policy documents will be briefly reviewed.

The EU Green paper on European Strategy for Sustainable, Competitive and Secure Energy (SEC (2006) 317) sets the main priorities for EU energy strategy. The general EU policy objectives considered most relevant to the design of energy policy are: competitiveness of the EU economy, security of supply and environmental protection. These objectives should help to address central policy concerns such as job creation, boosting overall productivity of the EU economy, protection of the environment and climate change. Overall competition of economy is pursued by liberalizing the EU electricity and gas markets and restructuring of energy sector. For fostering competitiveness of the EU economy and concomitant income and added value creation, the promotion of one internal market at Union levels is considered essential. Cross-border trade on level playing-field terms would foster competition.

Security of supply is the priority concern of EU energy policy. The Green Paper on energy supply security (COM (2000) 769 final) states, that the EU will become increasingly dependent on external energy sources. It was stressed in this paper that the EU has very limited scope top influence energy supply conditions but it can intervene on the demand side mainly by promoting energy saving in buildings and transport sector. The EU is not in position to respond to the challenges of climate change and to meet its Kyoto protocol commitments. The Green Paper identifies two main policy priorities: controlling the growth of demand and managing supply dependency.

For the controlling of demand growth the fiscal and financial instruments should be used. Fiscal interventions in energy prices should remove distortions between alternative energy carriers and between member states and make energy prices reflect the real costs including environmental damage costs. The reduction of energy demand growth should be achieved transportation sector and buildings through stimulation of energy-efficient technology (regulation, certification, fiscal measures and funding of research and development).

The Commission's new Green Paper on energy efficiency COM (2005) 265 stress the importance of energy efficiency improvement for the controlling of demand growth and security of supply. According to estimates, the economic potential for improving energy efficiency in 2010 for all sectors combined is 20% of the total annual primary energy consumption of the current level.

Lack of information for consumers and manufacturers, technical barriers and financial obstacles also hamper investment in energy efficiency.

In general terms, efforts must be made to promote energy efficiency in other policies, notably in regional, transport, fiscal, research and development and international cooperation policies. More specifically, the following areas for action are proposed as priorities for the short and medium term:

1. Energy efficient buildings;
2. Energy-efficient household appliances and other end-use equipment;
3. Wider use of negotiated and long-term agreements on minimum efficiency requirements;
4. Increased dissemination of information;
6. INTERACTION OF CLIMATE CHANGE AND ENERGY SECURITY POLICY MEASURES

Therefore energy and climate change remain on top of the agenda of the European Union (EU). Rising oil prices, regional concentration of conventional oil and natural gas, increasing demand for energy of emerging economies has ratified Kyoto Protocol committing itself to 8% GHG emission reduction in the period 2008–2012 from the 1990 and took new obligations for 2020. Equally the New Member States are determined to meet their individual targets under the Kyoto Protocol. Therefore the GHG emission reduction in energy sector is the priority issue in EU energy policy.

In March 2000 the Commission launched the European Climate Change Programme (ECCP). The ECCP led to the adoption of a range of new policies and measures, among which the EU’s emissions trading scheme, which will start its operation on 1 January 2005, will play a key role. As a result of the EU’s and individual Member States actions, the latest monitoring data indicates that the European Union has delivered on its long-standing commitment to stabilize emissions of CO2 at the level of 1990 in the year 2000. The EU-15 is committed to deliver the collective 8% cut in emissions by 2008–2012 to which it signed up under the Kyoto Protocol. The monitoring mechanism and its review, as well as the EU’s emissions trading scheme and the link with the Kyoto flexible mechanisms (JI and CDM) are key elements of the EU’s climate change strategy.


During the first phase of the ECCP1 (European Climate Change Programme, concluded in June 2001) the idea of a Directive promoting the use of heat from renewable energy sources was put forward. This legislation would complement other types of actions mentioned in the Commission’s 1997 White Paper on renewable sources of energy and it would be modelled on the format of the RES-E directive, i.e. covering targets, support schemes, certification, easier administrative procedures, etc. for heat from biomass (e.g. local space-/hot water heating, CHP and distributed heat, district heating), active solar systems (e.g. local space-/hot water heating), geothermal sources (including heat pumps).

Therefore the main targets of EU energy policy are: increase of energy security, opening of energy markets, promotion of renewables and cogeneration, increase of energy efficiency and reduction of impact on environment.

together with decreasing stocks within the EU, the alleged use of energy as a "political weapon" by politically unstable regions, as well as rising emissions of greenhouse gases (GHG) and their adverse effect on the global climate are just some of the issues associated with current patterns of energy use. Policy makers in the EU are aware of the pressing nature of these issues. The recent initiative to develop a sustainable integrated European climate and energy policy is a clear indication of this. While EU energy policy for the last 40 years has in principle been confined to the narrow fields of nuclear energy and coal, the EU and its Member States are starting to develop a coherent internal and external energy strategy or "vision" to ensure the competitiveness of European industries while at the same time combating climate change and ensuring security of energy supply [6].

In Table 4 the interaction of climate change and energy security measures are presented based on EU energy policy analysis. As it was mentioned above in the centre of the new energy policy is the EU's commitment to reduce its greenhouse gas (GHG) emissions by at least 20% by 2020 compared with 1990 levels, increasing energy efficiency by saving 20% of its energy by 2020 and increasing the share of renewable energy sources in the total energy mix to 20% by 2020, while aiming for a 10% biofuel component in vehicle fuel by 2020. These measures to reduce GHG emissions have mainly positive impact on energy security as one can see from information provided in Table 4.

<table>
<thead>
<tr>
<th>Energy option</th>
<th>Climate change impact</th>
<th>Energy security impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Changes to the power generation mix</td>
<td>Promoting renewable energy sources</td>
<td>Zero GHG emissions</td>
</tr>
<tr>
<td></td>
<td>Switch from lower to higher carbon content fossil fuels</td>
<td>Higher GHG emissions</td>
</tr>
<tr>
<td></td>
<td>Switch from higher to lower carbon content fossil fuels</td>
<td>Lower GHG emissions</td>
</tr>
<tr>
<td>2. Changes in the mix of transport fuels</td>
<td>Increase in biofuels use</td>
<td>Zero GHG emissions</td>
</tr>
<tr>
<td></td>
<td>Increase in natural gas use</td>
<td>Marginally positive and depends on alternative</td>
</tr>
<tr>
<td>3. Increasing import diversity</td>
<td>Depends on country</td>
<td>Positive</td>
</tr>
<tr>
<td>4. Increasing domestic production of fossil fuels</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>5. Increasing domestic production of fossil fuels</td>
<td>Depends on the fuel</td>
<td>Positive</td>
</tr>
<tr>
<td>6. Energy efficiency measures</td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>7. Clean energy technologies</td>
<td>Positive</td>
<td>Positive as energy efficient</td>
</tr>
<tr>
<td>8. Carbon capture and storage (CCS)</td>
<td>Positive</td>
<td>Positive</td>
</tr>
</tbody>
</table>

The development of carbon capture and storage (CCS) technologies is also a crucial factor in securing future energy supplies as well. The development of EU's carbon market and an open and competitive internal energy market would also help to increase energy security however all policies and measures needs to be harmonized before implementation by making assessment of these measures impact on the main ES sustainable energy policy development goals: GHG other pollutants emission reduction, increase of energy efficiency, increase of use of renewable energy sources, increase of energy security. This assessment of energy policy packages can help to ensure a synergetic effect of policies and reduce costs of policies and measures.

7. CONCLUSION

The recent EU initiative to develop a sustainable integrated European climate and energy policy packages indicates the priorities of EU energy policy and close interaction between climate change mitigation and increasing energy security.

Integrated policies packages can provide for harmonized policies and synergy effect of policies. Policies assessments should be based on their impact on
the main EU sustainable energy policy development goals: GHG other pollutants emission reduction, increase of energy efficiency, increase of use of renewable energy sources, increase of energy security.

The external costs of climate change and energy security can be used for policies impact assessment in monetary terms and help to cope with the problems of trade-off between policies.

Results on estimate change and external costs obtained during EU Cases project can be treated as the first step in creating framework for integration of such type of costs in decision making in energy policy and selecting harmonized policy packages able to achieve energy policy goals at least cost.

ACKNOWLEDGMENT

This article has been produced with the financial assistance of the European Commission FM 6 project under thematic priority: Sustainable energy Systems CASES (Cost Assessment of Sustainable Energy Systems) http://www.feem-project.nl/cases/ but views expressed herein are those of authors and can therefore in no way be taken to reflect the official opinion of the European Commission. The project will run until September 2008.

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