www.serd.ait.ac.th/reric

External Costs of Energy Security and Climate Change

Dalia Streimikiene*[1]

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 green house 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 SO_2, 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:

***Lithuanian Energy Institute, Breslaujos 3, LT-44403, Kaunas, Lithuania.

[1]Corresponding author;
Tel: +370 37 40 19 58, Fax: +370 37 35 12 71.
E-mail: dalia@mail.lei.lt.

- 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 form 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 CO_2) have been made. The estimates range from slightly negative (< 0) to over 400 USD per ton CO_2 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 CO_2, 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 CO_2 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 CO_2 at a particular date; hence it is another word for the marginal (social) cost of CO_2 emissions. It is measured as the present value of the impacts of one tonne of CO_2 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/tCO_2) 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 review of the evidence, the report concludes that the benefits of strong and early action far outweigh the costs of not acting. Climate change will affect the basic elements of life for people globally - including in relation to access to water, food production, health and environment, potentially affecting hundreds of millions of people. Using the results from an integrated assessment model (the PAGE model), the review estimated that the total damage costs of climate change could be at least 5% of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more. The review suggested a SCC of € 85 per ton of CO_2, which is considerably higher than the UK government's "illustrative value" of € 28 per ton, and also far out in the right tail of Tol's probability density function [11]. In contrast to these high costs of inaction, the costs of action - reducing greenhouse gas emissions to avoid the worst impacts of climate change - can, according to Stern, are limited to around 1% of global GDP each year.

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 Mendelssohn *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 understate 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 green house 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 for unit of emissions were evaluated for CO_2, CH_4 and N_2O, 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 CO_2 emissions are in quite good agreement. External costs of other GHG emissions are in quite different range. The highest damage costs are associated with N_2O emissions; however damage costs of N_2O 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.

	Damage costs	**Avoidance costs**
	2000-2009	2010
CO2	20.66	19
CH4	747.26	399
N2O	27202.90	5890
SF6	1260.64	

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

	Marginal damage cost
Nuclear	0.0599
Heavy oil condensing power plant	0.9311
Light oil gas turbine	1.8409
Hard coal condensing power plant	3.5581
Hard coal Integrated Gasification Combine Cycle ((IGCC) without CO_2 capture	3.6321
Lignite condensing power plant	3.8477
Lignite IGCC	3.8899
Natural gas combined cycle	1.8385
Natural gas turbine	2.7465
Hydropower run of river 10 MW	0.0541
Hydropower run of river <100 MW	0.0386
Hydropower run of river >100 MW	0.0348
Hydropower dam	0.0684
Hydropower pump storage	0.0617
Wind on-shore	0.0412
Wind of-shore	0.0322
Solar Photovoltaic (PV) roof	0.2428

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 on 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 CO_2 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 CO_2 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;

[5] Third-party financing, guarantee of results and other creative financing schemes;
[6] Energy efficiency in the electricity and gas sectors and combined heat and power (CHP);
[7] Energy management and public and cooperative technology procurement.

For managing supply dependency the Green Paper on security of supply suggests the stimulation of renewables by internalization of social costs in the energy prices and strengthening of supply infrastructure networks with due regards to environmental impacts. Green Paper on energy security emphasizes the role of technology development. Technology may contribute to increase of energy efficiency, to achieving security of supply and reduction of GHG emissions, in particular by improving access to indigenous energy resources in particular renewable energy resources. The state aid is foreseen for promoting the use of RES and combined heat and power production by way of tax exemptions or reductions.

The White Paper on renewable sources White Paper for a Community Strategy and Action Plan on renewable energy sources COM(97) 599 final states that member states should formulate indicative targets contribute to the ambitious indicative target of doubling the overall share of RES in the EU by 2010. It sets an indicative target of 12% for the contribution by RES to the total primary energy consumption within EU by 2010 and contains a strategy and action plan to achieve this target. Pursuant to the White Paper on Renewables the Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market (hereafter called the *RES-E Directive)* was passed in 2001. It adds the indicative target contribution of 22.1% by renewables-based electricity to total EU electricity consumption in year 2010.

2003/30/EC Directive on the promotion of the use of biofuels or other renewable fuels in transport (*RF Directive*) sets that Member States must ensure by end of 2005 a 2 % minimum proportion of biofuels of all gasoline and diesel fuels sold on their market. In longer term the target is to achieve a share of 5.75 % of biofuels for transport in the total amount of fuels in Europe by 2010 and 20 % by 2020.

2002/91/EC Directive on the energy performance of buildings sets target to realize a savings potential of around 22 % by 2010 for energy used in heating, air – conditioning, hot water and lighting.

2004/8/EC Directive on the promotion of cogeneration based on a useful heat demand in the internal energy market aims to increase energy efficiency and improve security of supply by creating a framework for promotion and development of high efficiency cogeneration of heat and power based on useful heat demand and primary energy savings taking into account the specific national circumstances especially climate and economic conditions.

All these directives have positive impact on GHG emission reduction and achieving of Kyoto target. EU 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 CO_2 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.

The Green Paper on greenhouse gas emissions trading within the European Union COM (2000) 87 sets the main blueprints for the introduction of GHG emission trading scheme in EU. In January 2005 the European Union Greenhouse Gas Emission Trading Scheme (EU ETS) commenced operation as the largest multi-country, multi-sector Greenhouse Gas emission trading scheme world-wide. The scheme is based on Directive 2003/87/EC, which entered into force on 25 October 2003.

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.

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 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 4. Interaction of climate change and energy security measures.

Energy option	Climate change impact	Energy security impact
1. Changes to the power generation mix		
Promoting renewable energy sources	Zero GHG emissions	Renewables can be often sourced domestically
Switch from lower to higher carbon content fossil fuels	Higher GHG emissions	Coal is relatively secure source of energy because many countries have domestic suppliers
Switch from higher to lower carbon content fossil fuels	Lower GHG emissions	Depends on the country
2. Changes in the mix of transport fuels		
Increase in biofuels use	Zero GHG emissions	Marginally positive
Increase in natural gas use	Marginally positive and depends on alternative	Neutral
3. Increasing import diversity	Depends on country	Positive
4. Increasing domestic production of fossil fuels	Negative	Positive
5. Increasing domestic production of fossil fuels	Depends on the fuel	Positive
6. Energy efficiency measures	Positive	Positive
7. Clean energy technologies	Positive	Positive as energy efficient
8. Carbon capture and storage (CCS)	Positive	Positive

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 external costs if climate change and energy security 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.nt/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.

REFERENCES

[1] Hohmeyer, O., 1988. *Social Costs of Energy Consumption.* Berlin: Springer Verlag.

[2] Frischknecht, R., 2003. Ecoinvent Database Methodology. In *Proceedings of the Special LCA Forum*. Lousane, Switzerland, 5 December. Lausanne: ETH.

[3] Commission of the European Communities. 1995. *Joule Programme. ExternE: Externalities of Energy*. Luxemburg.

[4] European Commission. 1998. ExternE – *Externalities of Energy Vol. 7. Methodology* 1998 Update. Luxemburg.

[5] European Commission. 2007. *An Energy Policy in Europe.* COM (2007) 1 final, Brussels.

[6] Behrens A. and C. Egenhofer. 2007. An initial assessment of policy options to reduce - and secure against - the costs of energy insecurity. In *CASES WP5 Report (2) on Policy Assessment of Energy Security Measures Incorporating Externality Measures*. Brussels: Centre for European Policy Studies.

[7] Kuik, O., Brander, L., Nikitina N., Navrud, S., Magnussen, K. and Fall, E.H., 2007. A Database of Studies on Energy-related External Costs due to Land Use Changes, Acidification and Eutrophication, Visual Intrusion and Climate Change. In *CASES WP3 External Costs Estimate Database.* Brussels: Institute for Environmental Studies (IVM), VU University of Amsterdam.

[8] Porchia R. and A. Bigano. 2008. Development of a set of full cost estimates of the use of different energy sources and its comparative assessment in EU countries. In *CASES WP6 report. Total Energy Costs in EU Countries.* Milano: FEEM.

[9] European Commission. 2004. Work Package 6: Revision of external cost estimates. In *New Elements for the Assessment of External Costs from Energy Technologies (NewExt*). Final Report. (Contract No. ENGI-CT2000-00129. 2004).

[10] Schlesinner, L. and L. Nielsen. 1997. *External Costs related to Power Production Technologies. ExternE National Implementation for Denmark.* Roskilde: Risø National Laboratory.

[11] Tol, R.S.J., 2005. The marginal damage costs of carbon dioxide emissions: An Assessment of the uncertainties. *Energy Policy* (33): 2064-2074.

[12] Roughgarden, T., and S.H. Schneider. 1999. Climate change policy: quantifying uncertainties for damages and optimal carbon taxes. *Energy Policy* (27): 415-429.

[13] Tol, R.S.J., 1999. The Marginal Damage Costs of Greenhouse Gas Emissions. *The Energy Journal (*20): 61-81.

[14] Watkiss, P., 2006. *The Social Costs of Carbon (SCC) Review - Methodological Approaches for Using SCC Estimates in Policy Assessment.* Final Report to Defra. London: Defra.

[15] Watkiss, P., Downing, T., Handley, C. and Butterfield, C., 2005. *The Impacts and Costs of Climate Change.* AEA and Stockholm Environment Institute, Report prepared for the DG Environment, Brussels: EC.

[16] Stern, N., 2006. *The Economics of Climate Change. Cabinet Office* - HM Treasury, Cambridge: Cambridge University Press.

[17] Nordhaus, W.D. and J.G. Boyer., 2000. *Warming the World: Economic Models of Global Warming.* Cambridge: MIT Press.

[18] Mendelsohn, R.O. and M.E. Schlesinger., 1999. Climate-Response Functions. *Ambio* (28): 362-366.

[19] Tol, R.S.J., and H. Dowlatabadi. 2001. Vector-borne Diseases, Climate Change, and Economic Growth. *Integrated Assessment* (2): 173-181.