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INTERNALIZING OF EXTERNAL COSTS IN ELECTRICITY GENERATION

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This article seeks to describe methodology for taking into account the damage cost caused to the environment by electricity generation, so-called internalizing of external costs, i.e. ExternE, and presents examples of using it in Eastern European countries. The cost rates calculated on the basis of ExternE methodology are tested on data of Estonian oil shale-fired power plants. Also the issue of optimality of the external costs in electricity producer price is discussed.

Introduction

In the recent decade energy and environmental policy developers in Europe have increasingly more focused on working out methodologies for estimating the monetary value of environmental damage – on assessment of external costs, as well as on introducing various economic and tax policy measures for internalizing the external costs in the price of respective product. In 2005, a new version of the methodology for internalizing the external costs of energy production and consumption − ExternE 2005 [1] − and an integrated software tool for environmental impact pathway assessment − EcoSense [2] − were developed as a result of a joint research by European and US scientists. Its implementation in practice is being tested in several European Union (EU) member states. The method enables to assess damage cost caused by production and use of energy to environment and human health.

The concept of external costs has a broader meaning in the ExternE 2005 methodology: the external costs are divided into those included in the

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producer price and those, which are not. Estimation and internalization of external costs as economic incentives in implementing tax reforms presumes a most precise assessment of actual environmental damage cost to human health and ecosystems. Unfortunately the consistency of the relevant research in Estonia has almost stopped.

The ExternE methodology was implemented for internalizing damage-based external costs in Czech Republic, Poland and Hungary for coal, brown coal and natural gas-fired power plants, and in road and railway transport [3, 4]. The effect of air pollution on human health, field crops, buildings and climate was assessed. In these studies, on the basis of actual initial data, damage rates have been worked out for different air pollutants. The damage cost rates have been used for calculating external costs in power plants in abovementioned countries. The same factors have been tested on the basis of analogy by the present authors in the assessment of external costs of Estonian oil shale-fired power plants (Narva PP) located near the eastern border town Narva.

The question of optimal size of external costs in production cost arises while using the external costs calculated with the ExternE methodology in the course of ecological tax reform. The ExternE methodology recommends to calculate a socially optimal environmental damage cost where the marginal damage cost is equal to the marginal abatement cost of adverse environmental impacts [1]. However, it is not easy to implement this principle, as economic interests of producers and consumers differ, and the "polluter pays principle" is interpreted in different ways.

Development of the methods for assessment of external costs

The concept of external cost was introduced to draw attention to the environmental damage cost that has not been included in producer price in the 1970-ies. With the development of environmental economics and policy various economic instruments such as natural resource charges and pollution charges have been introduced in an increasingly wider scope. Some of the external costs are internalized in producer price already. Development of this process is reflected in corresponding research [5–7 etc.] and numerous legislations [8–11 etc.]. The issues of estimating the external costs of oil shale-based electricity generation in Estonia have been discussed by the present authors in *Oil Shale* earlier (in 2004) [12].

External costs can be internalized either technologically or politically. In the former case environmental damage and along with it external costs are reduced as a result of changing the technology or building a waste treatment facility. Technological measures are effective when the costs of the measure are lower than abatement cost of environmental damage. With political internalization of external costs environmental damage would not change immediately, as only an administrative or economic incentive (for example pollution charge) is created for the abatement. Inclusion of external cost will raise the producer price of polluting enterprise thus reducing the competitiveness of this product. In that case the external costs C consist of two components: external cost included in producer price − C_a, and the external cost not included in the price − C_m. The environmental costs are so far included into oil shale-based electricity producer price through natural resource charges and pollution charges in Estonia [12] and reflect the external cost component C_a, which is still much smaller than C_m. In several EU member states the internalizing of the external cost component C_m in economic efficiency calculations and tax policies has significantly accelerated.

The environmental impacts of energy production and consumption discussed in the ExternE methodology are broadly divided into four groups:

- pollutants and energy (heat, radiation) into the air, water and soil, that may cause damage to human health, crops, buildings, ecosystems etc.;
- global climate warming caused by emission of greenhouse gases;
- accidents related to extraction, transport, processing and utilization of energy carriers or other accidents;
- security of energy supply, unexpected fuel price rise risks etc.

Local research of the environmental impacts demands co-operative effort of experts of various specialties to conduct analyses, generalize results and transform quantitative indicators to monetary value assessment. With the models developed under the ExternE methodology it is possible, using the principle of analogy, under definite conditions to roughly evaluate the environmental impacts and external costs also without detailed exploration of a particular region, transferring the values of another region (country, object) to this region (value transfer). Naturally, the analysis of suitability of primary data to be transferred to a particular region (area) under consideration and the relativity of the result should be followed. According to the ExternE methodology, the value transfer with income adjustment is the most frequently used method. Definitely, also other factors need to be considered: actual level of pollution of environment, suitability of transferring the damage cost functions to another region, climate conditions etc. The authors have adopted the described approach.

The ExternE methodology applies various models of dispersion of air pollutants, health risks, human life and lifetime assessment methods, ecological sensitivity assessment model EcoSense [2], etc.

Major greenhouse gases CO_2, CH_4 and N_2O stay long enough to spread in the atmosphere all over the globe. Therefore, it is sufficient to register their emissions only, no specific local range dispersion calculation is needed. Numerous complex models for the global dispersion of greenhouse gases and accounting of external costs have been developed, which have been described also in the ExternE methodology 2005 [1].

In the assessment of regional dispersion of air pollutants one must take into account chemical reactions and transformations of pollutants. For example, in the case of the formation of sulphates from SO_2, the ExternE methodology uses the Windrose Trajectory Model (WTM). Though the concentrations of heavy metals and toxic organic substances in the air from transportation exhaust gases are very small, they pass a complex pathway in the ecosystems, cumulate in the biological food chain and are ingested with food to human organism in substantial quantities already. This creates an additional risk to health, which is assessed with the model WATSON (integrated WATer and SOil environmental fate, exposure and impact assessment model of Noxious substances).

An important instrument in the ExternE methodology is the assessment of adverse effects of pollutants and other environmental impacts on human organism with the help of dose-response function (DRF). In principle, it means direct measurement of the quantity and physical impact of a pollutant absorbed by a receptor. To ease the situation, instead of the DRF function the concentration-response function (CRF) is used in practice for the assessment of the damage caused by pollutants. It is based on the concentration of a pollutant in the human environment, in respect of which various human health indicators, such as increment of cases of illness, increase in hospital days, shortening of lifetime etc., are calculated. In constructing a CRF function it is most complicated to eliminate the impact of other factors that damage human health.

The EcoSense model consists of the modules for assessing dispersion of pollutants and environmental impacts, the primary data of which can be flexibly changed, according to local conditions, by the users. In principle, with the EcoSense model it is possible to estimate damage caused by pollutants to human health, agricultural crops, building materials etc. Sufficiently trustworthy DRF and CRF functions for environmental impacts are still missing at present. The current version of the EcoSense model covers 14 most frequent air pollutants only.

Monetary valuation of the external costs has been most discussed in the ExternE methodology from the aspect of human health risks assessment. The most frequently used methods of valuation are compensation of health risks with wages and assessment of health risks by questioning people. The cost of mortality is measured either by means of the value of a prevented fatality or the value of lost life years. For the valuation of health risks by means of population surveys to study health related preferences and opinions the Contingent Valuation Method (CVM) has been used, which helps to identify demand for goods in “hypothetical market”. The CVM method enables to monetarize the goods that have no real market and price, for example abatement of health risks caused by air pollution.

Assessments of the monetary value of illnesses caused by adverse environmental impacts are based on experimental studies of CRF and DRF functions for pollutants, also statistics on medical treatment expenses. However, the adverse environmental impacts with verified causal relationships account for a very small share of external costs. Adverse environmental impacts act in correlation with other health hazards, but it is almost impossible to estimate their effect individually. Compared with the assessment of human health risks, it is somewhat less complicated to assess damage to the natural environment, buildings or various objects. For example the costs to avoid or mitigate the contamination of soil, water or air in power station are easily accountable and should be considered as a part of producer price.

Examples of using ExternE methodology in selected East European countries

One of the first implementation projects of the ExternE methodology was ExternE-Pol (Externalities of Energy: Extension of Accounting Framework and Policy Applications), which was concluded in 2004. Objectives of the project were to further improve the ExternE methodology and test it on real data based on energy production units in Poland, Czech Republic and Hungary [3, 4] to prepare more state-of-the-art information for adoption of important environmental policy decisions in the abovementioned countries.

The project specified the environmental impacts database, improved monetary valuation of the protection of cultural monuments related external costs, compared external costs of power plants in the countries and also calculated external costs of road transport for Czech Republic. Calculations of the external costs of power plants were based mainly on adverse environmental impacts of air pollution. Investigations involved the effect of air pollution on human health, agricultural crops, building materials and climate change mitigation (costs of the compliance with Kyoto targets). External costs were calculated using the EcoSense model for evaluation of the regional pollution effect of power plants (up to 1000 km from the source of pollution) accounting for over 90 percent of the external costs of air pollution by power plants. The effect of local pollution (up to 50 km from the source of pollution) was calculated by means of a simplified model.

The three countries under study have quite a different fuel structure of the power generation sector. Polish power engineering relies, to the extent of 95%, on hard and brown coal-fired power plants. Total electricity generation in 2002 was 143 TWh. The share of renewable energy sources was only 0.6%. Czech Republic produced 67% of electricity from hard and brown coal, 25% in nuclear power plants and 4% from renewable energy sources, mostly hydro energy. Total electricity output was 70 TWh. Hungary produced 39% of electricity in nuclear power plants, 30% from natural gas, 25% from hard and brown coal and 5% from oil. Total electricity output was 36 TWh.

The ExternE-Pol project has calculated external costs of air pollution in selected power plants for each particular fuel. **External costs related to extraction, processing and transport of fuels were added up on the basis**

of European average indices and expert estimates, which made the calculations less accurate. Also specific damage (EUR/t) caused by each of the major air pollutants and fuels has been calculated for all reference power plants. Abovementioned indicators have been accommodated by the authors in their recent study on calculation of external costs of Estonian power plants [13].

Testing of ExternE methodology on Estonian data

For testing the ExternE methodology in Estonia, the external costs of Narva oil shale-fired power plants were calculated following the approach used in ExternE study reference power plants in Poland and Czech Republic. Considering that no recent local studies of actual environmental impacts have been conducted in Estonia, assessments of damage cost to the environment caused by generation of electricity from oil shale are based on external cost calculations performed in ExternE-Pol projects [4]. Bearing in mind the reliability problems of primary data from other countries used in the ExternE methodology and of the transfer of valuation results, technical and environmental parameters of power plants discussed in ExternE-Pol and of oil shale-fired power plants have been previously analyzed and compared. On the basis of the analysis, brown coal-fired reference power plants in Czech Republic and Poland to be considered comparable to Estonian oil shale power plants have been selected. The technical parameters and estimated external costs of power plants under discussion are presented in Table 1.

Table 1. **Technical data of the reference power plants (2002) [4]**

	Czech	Polish
Fuel	Brown coal	Brown coal
Plant type	Dry-bottom boiler, FGD*, DENOX** and dedusting	Pulverized-fuel power plant with FGD, DENOX and dedusting
Installed capacity (el.), MW	1000	4410
Net efficiency, %	32.8	33.2
Full-load hours per year	6784	6224
Net annual electricity generation, GWh	6270	25422
Emissions:		
SO_2	8679 t; 1.38 t/GWh	1777 mg/Nm^3
NO_x	15967 t; 2.55 t/GWh	380 mg/Nm^3
Particulates	617 t; 0.1 t/GWh	24 mg/Nm^3
CO_2	2270530 t; 362 t/GWh	1642 t/GWh
Estimated external costs, EUR/100 kWh	**3.7**	**6.5**
incl. CO_2	2.0	1.9

* FGD – flue gas desulphurization
** DENOX – low NO_x burner

Damage costs (EUR/t) estimated in the ExternE-Pol project [4] in respect of major air pollutants and fuels at the brown coal-fired power plants in Czech Republic and Poland are presented in Table 2. As one can see, damages caused by SO_2 are rather similar, and those caused by NO_x and particulates quite different in comparison of the Czech and Polish brown coal-fired plants. CO_2 damage costs are for all fuels and reference power plants agreed to be 19 EUR/t, which equals to the costs of compliance with Kyoto target in Germany by 2010.

Table 2. **Estimated damage costs by pollutants (2002) [4]**

Pollutants	Damage costs, EUR/t	
	Czech PP	Polish PP
SO_2	5682	6066
NO_x	3042	1169
Particulates	13099	8766
CO_2	19	19

It should be hereby underlined that alike the scenario „EC" in article [12], it is an hypothetical valuation of external costs only, the actual implementation of which in Estonia is not feasible in the short term. However, below we have used these damage cost rates for contingent comparative valuation of full external costs of oil shale-based electricity generation at Narva PP. Electricity net output and emissions of pollutants conform to the actual Narva PP data for the financial year of 2004/2005 (01.04.2004-31.03.2005) [14]. Calculations of the damage caused by oil shale-based electricity have been performed on the basis of above estimated damage cost rates of the Czech and Polish brown coal-fired reference power plants. The calculations are presented in Table 3.

One could notice a good similarity of results of external costs calculations of oil shale-fired power plants compared to Czech and Polish plants when applying their damage cost rates. Firstly, by applying the damage cost rates of Czech reference plants, total oil shale power plants damage cost is MEUR 752 or 8.8 EUR/100 kWh (1.38 EEK/kWh). Secondly, using the Polish damage cost data, the total damage caused by pollution in oil shale-based electricity generation would be MEUR 696 or 8.1 EUR/100 kWh (1.27 EEK/kWh). Across major air pollutants approximately half of the damage cost in both versions is caused by sulphur dioxide; damage cost caused by CO_2 in both cases is approximately a quarter, i.e. 2.2 EUR/100 kWh.

Comparing the results with the environmental costs of oil shale-based electricity generation calculated on the basis of environmental charge rates effective in Estonia in the economic year of 2004/2005 and even on the basis of pollution charge rates established in enacted in 2006 Environmental Charges Act, the air pollution damage cost only exceeds several times the

Table 3. **Valuation of environmental damage costs caused by oil shale-based electricity generation at Narva Power Plants by analogy of brown coal-fired plants**

Indicator	Emissions and damage rates	Estimated environmental damage cost		
		total (electricity + heat)	of electricity generation	
			total	per unit
Net electricity generation, GWh			8558	
Emissions 2004/2005				
CO_2, th t	10758.3			
SO_2, t	67075.2			
NO_x, t	10380.4			
Particulates, t	15664.8			
Heavy metals, t	110.4			
Estimated damage costs according to the brown coal power plants data				
Czech power plant:	EUR/t	MEUR	MEUR	EUR/100 kWh
CO_2	19	204.408	187.033	2.2
SO_2	5682	381.121	348.726	4.1
NO_x	3042	31.577	28.893	0.3
Particulates	13099	205.193	187.752	2.2
Total damage cost, MEUR		**822.299**	**752.404**	
EUR/100 kWh			**8.8**	**8.8**
EEK/kWh			**1.38**	**1.38**
Polish power plant:	EUR/t	MEUR	MEUR	EUR/100kWh
CO_2	19	204.408	187.033	2.2
SO_2	6066	406.878	372.294	4.4
NO_x	1169	12.135	11.103	0.1
Particulates	8766	137.318	125.646	1.5
Total damage cost, MEUR		**760.738**	**696.075**	
EUR/100 kWh			**8.1**	**8.1**
EEK/kWh			**1.27**	**1.27**

total sum of environmental costs in the oil shale-based electricity producer price. The environmental costs (primarily environmental charges), based on calculations performed by the authors, for the economic year 2004/2005 were 0.25 EUR/100 kWh only; and 0.6 and 1.4 EUR/100 kWh according to the forecasts for 2009 and 2015, respectively. The total damage cost based on external costs calculated by the present approach are approximately equal to total electricity producer price of oil shale-fired power plants.

The ratio of the estimated external costs to Estonia's gross domestic product (GDP) 9–10% in 2004 is relatively high compared to the respective indices of Czech Republic – 2.5% and Poland – 4.8% in 2002. The hypothetical external costs of electricity generation per capita are also much bigger – EUR 500–550 in Estonia (in 2004), compared to Czech Republic – EUR 178 and Poland – EUR 219 (in 2002).

Optimality of external costs

On the basis of the above-described results it can be decided whether the environmental costs calculated by following the approach of the Czech and Polish brown coal-fired power plants can be conditionally taken as full external costs of oil shale-based electricity generation (C). The authors are of the opinion that these costs should be treated rather as the hypothetical maximum rate of external costs of oil shale-based electricity (C_{max}). The minimum external costs might be the environmental costs internalized in the electricity producer price on the basis of the environmental charges established by Estonian laws (C_a). The main issue still remains how to find the optimal external cost (C_{ao}) internalized in electricity generation price in the range of [C_a; C_{max}]. It is most expedient to combine the ExternE method based approach and the results of local research of actual external costs (environmental damage costs), at the same time taking into account also social tolerance (which could be characterized with the maximum price of electricity the population is capable to pay). The respective methodological principles have been explained by the authors in [13], where also the recommendations for internalizing optimal external costs in electricity producer price (C_{ao}) in Estonia are given.

It is relevant to present a brief overview on the process of formation of external costs (C_a) in Estonian electricity generation sector, which has been performed via establishment of environmental charges. In the following the first attempt of internalizing of external cost of electricity generation C_a performed in the late 1980-ies is described. There has been a relatively small number of studies on environmental damage cost performed in the air pollution sector to establish pollution charges. Nevertheless, a comprehensive system of natural resource charges and pollution charges was established since 1991 [15]. The overall damage cost caused by air pollution has been roughly estimated and based on the prices in 1989/1990. Thereafter, the list of major air pollutants was established and appropriate pollution charge rates calculated [16]. In the atmospheric pollution sector additionally the human health factors were included in the form of four different classes of toxicity of pollutants [17, 18]. The described tax reform was the very first one in the former Soviet Union.

Considering the fact that Estonian economy passed great changes in transition from planned to market economy in the beginning of the 1990-ies and the economic and social situations were extremely unstable, the charge rates were established to be very low. At the same time the extremely fast inflation in the country deteriorated the impact of environmental charges as the planned impetus to save the environment. In 1994, the charge rates for mineral resources and water usage, also pollution charge rates were raised 1.4 times, and in 1995 and 1996 were adjusted according to the rise of the consumer price index (inflation), and from 1997 to 2001 the environmental charge rates were raised by an average of 20% annually [19]. The pollution charge rates continued to rise at the same rate on the basis of the Amendment Act to the Pollution Charge Act also in the period 2001–2005 [9]. In 2000–2002, broad-bottomed discussions were conducted with the participation of ministries, local governments, entrepreneurs and organizations to find an acceptable consensus for different interest groups to raise the environmental charge rates until 2015. As a result of these discussions the need to stop supporting economic development at the cost of the natural environment was acknowledged and a so-called *ecological tax reform* (ETR) launched. The objective of the reform is to give entrepreneurs and population a clear signal of that Estonia wishes to use its natural resources and environment in a most rational, efficient and sustainable way.

The principles of ecological tax reform were approved by the Estonian government on July 7, 2005. In the first stage of ETR, the Ministry of the Environment prepared a draft law of environmental charges, which was approved by the government on September 9, 2005 and adopted by the Estonian Parliament on December 7, 2005 [11]. The new charge rates of natural resources and pollution charge rates came into force on January 1, 2006. These involved an almost 2-fold rise of environmental charge rates for 2006 compared to 2005. The charge for the special use of water is annually raised by 10 percent.

Validity and economic effect of environmental charges have been recently studied at the example of an analysis of macroeconomic effect of the pollution charge for carbon dioxide (CO_2) in the frame of the project "Analysis of the Macroeconomic Influence of the CO_2 Tax Implementation in Estonia" conducted by the Center of Strategic Initiative in co-operation with Prof. A. Markandya (University of Bath in UK). Basic principles of the approach used and the results are presented in [20–22].

In the course of preparation of ETR, the impact of increasing costs on the economy as a result of the implementation of new Environmental Charges Act (2005) has been analyzed also in the research [23] by a working group of the Ministry of Economic Affairs and Communications, consisting of the experts of various institutions. They evaluated the impact of these costs through the price rise of electricity and other energy resources. In parallel, the energy expenses in household expenditure and their effect on households with different standard of living have been thoroughly studied by A. Laur and K. Tenno [24, 25].

The findings of the abovementioned studies enable to state that a continuing iterative increase in environmental charges in the future may lead to exceeding the level of socially optimal external costs of electricity generation, which already holds a threat to the cost of living and competitiveness of the Estonian economy. In order to prevent this, it is necessary to develop further on much deeper local research to identify actual environmental damage cost.

To identify environmental damage cost caused by electricity generation in Estonia, the most recent and comprehensive study [13] recommends to prepare a respective plan of various studies and continue the research to work out an applicable methodology for internalization of optimal external costs of electricity generation. In-depth studies are necessary to be launched for evaluation of the environmental damage cost. Relatively more studies have been conducted to assess damage costs to water resources, however, those results also require further development. Life Cycle Analysis-based overview of the water pollution problems of oil shale industry has been requested by the European Parliament. The study has been performed by the team of experts co-ordinated by Tallinn University of Technology [26]. Above all, specification of the environmental damage cost caused by oil shale extraction should be continued. A profound ecotoxicological comparative analysis of solid and liquid waste of Estonian and world oil shale industry is recently provided in [27]. Most complicated, however, is definitely the monetary evaluation of damage caused by air pollution to human health and ecosystems. Unfortunately, the consistency of these studies in Estonia is about to discontinue.

Concluding remarks

For assessment of adverse environmental impacts of production and use of energy the European and US scientists have developed an improved ExternE 2005 methodology for monetary valuation of external costs. According to this methodology, the environmental damage costs are divided into external costs incorporated in producer price in economic policy terms (C_a) and those not incorporated (C_m). The ExternE methodology has been implemented in Poland, Czech Republic and Hungary where full external costs have been calculated for electricity generation in power plants (project ExternE-Pol). This project included the assessment of actual environmental damage and calculations of air pollution damage rates for particular pollutants.

In fact, no recent research has been made in Estonia for monetary valuation of health damage and other adverse environmental impacts caused by oil shale-based electricity generation. Environmental damage caused by electricity generation is internalized in the generation cost in the form of enacted environmental and pollution charges, which essentially represent the external cost component C_a. For the assessment of the external cost component C_m and of total external costs (C), the damage rates of pollutants calculated in the project ExternE-Pol have been applied in Estonian oil shale-fired power plants. The estimated external costs exceed manifold the environmental costs (so far) internalized in the producer price of electricity generation. It is not realistic to internalize so high external costs in the electricity producer price in the short term. At the same time, results of such test calculations should be of interest as background information, and comparative calculations should be continued also for the assessment of external costs of other power generation technologies available in the country. A thought should be given also to extending the range of internalizing environmental impacts. For example, in addition to the four groups of impacts mentioned in the methodology ExternE 2005, also the abatement of recreative, cultural and aesthetic value of the natural environment due to energy production should be estimated.

Internalizing of external costs cannot be ignored while estimating the strategic environmental impact of the development plans for using Estonian oil shale either, particularly considering the optional plans under discussion at present to increase the volumes of oil shale processing from the present 15 up to 20 million tonnes. Based on the logic of ExternE methodology, it is important to find socially optimal external costs. For that the research of the impact of adverse impacts of pollutants from power generation and oil shale processing on human health should be restarted and other current environmental research continued.

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