Internalization of External Costs of Energy Generation in Central and Eastern European Countries

Máca Vojtěch and Melichar Jan and Ščasný Milan

Univerzita Karlova v Praze, Environment Center

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INTERNALIZATION OF EXTERNAL COSTS OF ENERGY GENERATION IN CENTRAL AND EASTERN EUROPEAN COUNTRIES

Vojtěch Máca
Jan Melichar
Milan Ščasný
Charles University Environment Center, Prague

Abstract

In this article a bottom-up approach to quantification of air pollution externalities from electricity generation is used to show that market-based instruments are not very effective in internalizing these external costs in six CEE countries. Although governments in CEE countries have regulated air emissions by imposing strict command-and-control measures, most of them have also introduced air emission charges and more recently taxes on electricity. We find however that the level of internalization by these two economic instruments is fairly low for existing fossil fired power plants ranging from 3% for coal- and lignite-fuelled plants to 31% for gas-fuelled plants. The picture improves if cross-subsidies for renewable electricity are accounted for but the internalization level is still below air pollution–related external costs, between 9% and 55% for coal- and oil-fired power plants. A substantial over-internalization by these three instruments is however encountered in the case of gas-fired power plants.

Keywords

air pollution, Central and Eastern Europe, economic instruments, external costs, internalization

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Introduction

Over the last 20 years during the transition to a market economy Central and Eastern European (CEE) countries have substantially reduced emissions from industrial sources (see e.g. Moldan & Hak, 2007). In spite of substantial improvements in emission intensity of electricity generation with respect to most airborne pollutants, these processes still impose significant burdens on society that are not fully reflected in production prices. These externalities in economic parlance include adverse health effects of pollution, loss of crop yield and biodiversity, soiling of building facades, accelerated corrosion of materials, and climate change impacts to name a few. If the market does not reflect all the costs of such damage, market prices do not provide the right signals for economic agents and thus cannot ensure optimal allocation of scarce resources. It is usually the governments' role to step in to ensure prices are right through certain types of regulation. The extent to which prices are corrected depends on the degree to which the external costs are internalized. The aim of our paper is to assess this level of internalization of external costs by environmental taxation and other market-based instruments in some CEE countries.

To fulfil this goal we first estimate the external costs for major electricity production systems in each of six CEE member states of the European Union—Bulgaria, Czech Republic, Estonia, Hungary, Poland, and Slovakia.[1] The scope of our assessment is, however, somewhat limited. We do not analyze the entire fuel-cycle of electricity generation; therefore external costs incurred as well as taxes and charges levied in upstream and downstream processes (e.g. mining or power plant decommissioning) are not accounted for. We also refrain from assessing climate change impacts. The electricity generation sector is predominantly subject to the EU emission trading scheme as a primary instrument of internalization. However, the experiences from the first trading period (2005-2007) showed substantial over-allocation of emission allowances in all six CEE countries, a trend which has persisted in the second trading period 2008-2012 (except in Estonia).

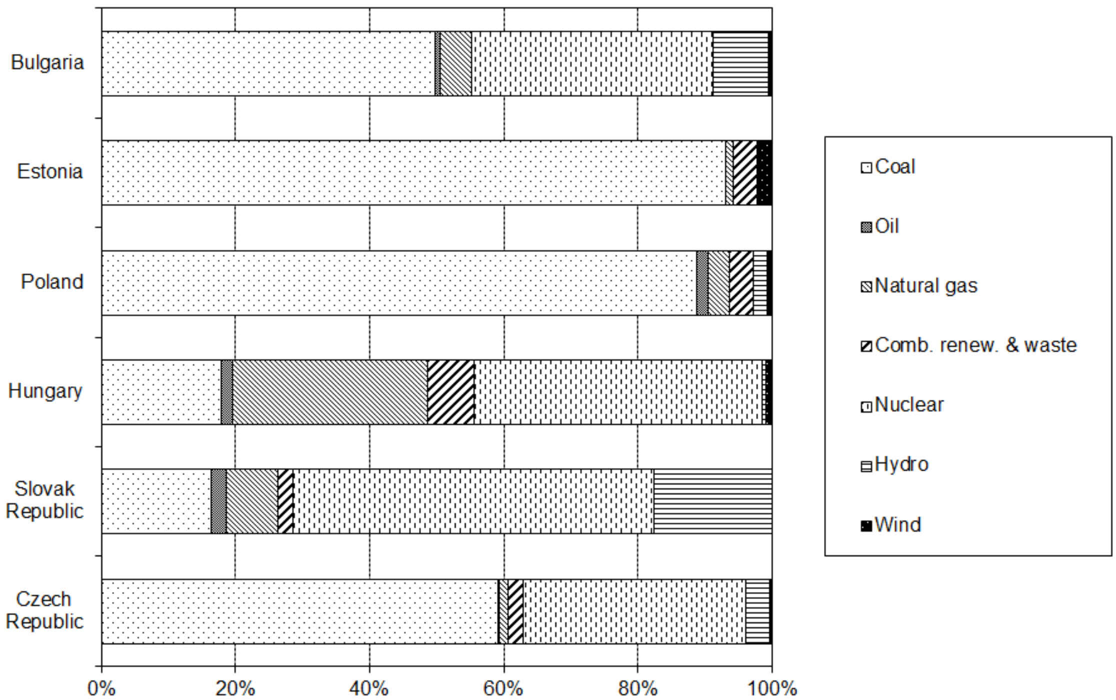
The paper is structured as follows: first, we provide a brief overview of energy production in CEE countries and review market-based instruments used in these countries. We then describe the methodology for the external cost assessment and proceed with a quantification of marginal external costs for representative power plants operated in the six CEE countries and analyze the rate of internalization of external costs using air pollution charges, electricity taxes as well as subsidies for renewable electricity production. Finally, we summarize our results and outline possible future work towards making a comprehensive assessment of external cost internalization.

Internalizing air pollution externalities in CEE countries

ELECTRICITY PRODUCTION IN CEE COUNTRIES

In 2009 gross electricity production in the six analyzed CEE countries amounted to 353 TWh. Coal and other fossil fuels are dominant energy sources used for electricity generation in this region. In fact, almost 65% of the total electricity production is generated by coal-fired power plants, nuclear power contributes 20%, natural gas less than 6% and other combustible fuels 4%. Renewable energy accounts for the remainder, with hydro power only contributing about 4%. A detailed breakdown of electricity production by fuel for the six countries of interest is shown in Figure 1.

Figure 1. Gross Electricity Production by Source (in TWh of 2009)



Source: OECD & IEA (2011)

Our assessment of the external costs is therefore focused on coal-fired and other fossil fuel propelled energy technologies. For each type of fossil fuel, we select and refer to particular power plants corresponding to the dominant fuel use in each country. The main characteristics of representative technologies (such as annual electricity production, type of fuel used and pollution emissions) are summarized in Table 1.

Table 1. Technology Characteristics

Country of origin of reference power plant	Czech Republic	Czech Republic	Slovakia	Hungary	Hungary	Hungary	Poland	Estonia	Bulgaria
Fuel used	lignite	natural gas	hard coal	lignite	natural gas	light oil	lignite	oil shale	hard coal
Installed capacity (GW/year)	4,758	242	1,552	4,746	1,407	2.30	29,509	8,500	5,392
Sulfur dioxide (tons)	10,400	0.13	3,409	3,336	151	0.90	130,678	67,075	21,684
Nitrogen oxides (tons)	9,707	81	2,107	5,930	458	2.20	43,867	10,380	3,577
Particulates (tons)	124	1.27	4,903	69	48	0	3,671	15,665	10,598
Carbon dioxide (kilotons)	5,266	121	1,665	6,110	862	2.30	31,970	10,800	8,040

We focus on environmental taxes and charges as the principal instruments for internalization in our assessment of the level of internalization of external costs. Following the traditional classification of environmental taxes (and charges), a distinction is made between resource charges, emission/pollution taxes and charges that are levied on extraction and production processes, while energy taxation is regularly levied on energy consumption (OECD, 2001, EEA, 2005).

POLLUTION CHARGES

All six new Member States apply some form of emission charges/taxes for a number of pollutants emitted into the atmosphere. Other pollution charges levied on emissions released to water and disposal of waste as well as charges for extraction of natural resources do not have, in general, much importance in relation to the energy production lifecycle in terms of rates and revenues.[2] Generally speaking, pollution taxes were adopted for their revenue-raising function rather than as serious incentives for polluters to reduce environmental burdens (Speck, McNicholas & Markovic, 2001). As suggested by Söderholm (2001) and also in line with Blackman and Harrington (2000), institutional deficiencies as well as more experience with, and relative ease of command-and-control regulation may have contributed to establishing this regulation in CEE countries in the first place.

In Bulgaria, an air pollution non-compliance fee is levied on emissions above a specified environmental standard (corresponding to the total volume of pollution based on the workload of the respective facility). The rates are currently set for 16 different polluting substances, including nitrogen oxides and sulfur dioxide and dust particles, differentiated further according to the geographical location of the emitting source. However, given that these standards are relevant only for non-compliant polluters these fees are marginal in terms of revenues: only about 0.7 million € was raised in 2005 according to the Bulgarian Ministry of Environment and Water.

In the Czech Republic the Air Protection Act of 2002 partially revised the rules on charging operators of stationary pollution sources. The polluters (except for small pollution sources below 200 kW) are charged according to installed capacity and volume of emissions of core pollutants (particulate matters, sulfur dioxide, nitrogen oxides, volatile organic compounds, polycyclic aromatic hydrocarbons and heavy metals) and two residual classes of other harmful substances (e.g. benzene and its compounds). The emission charges generate revenues of about 16 million € annually. In the course of the preparation of a new air protection law a substantial revision of pollution charges has been proposed, including reduction of the number of charged pollutants and a radical increase in charge rates (a tenfold increase has been proposed, but even if this was accepted, rates would remain below marginal abatement costs).

Estonia has been using environmental taxes and charges for air and water pollution since 1991. The fees have been continuously increased by around 10–20% annually since 1996. For non-compliant polluters a basic fee is multiplied by 10 (for exceeding limits) or by 20 (for operation without a permit). Unlike the majority of CEE countries, Estonia also charges for carbon dioxide emissions.[3] As of 2009, however, an excise tax is levied on the sale of electricity instead of a pollution charge for carbon dioxide emissions. Based on the 2009 amendment to the Environmental Charges Act, the air pollution charge rates for carbon monoxide, nitrogen oxides and volatile organic compounds, heavy metals and mercaptans are to increase by 5-10% annually between 2010 and 2015. Sulfur dioxide and particulate matter charge rates are to increase by 30%; only carbon dioxide emission charge rates (though from other sectors than electricity generation) will not change.

In Hungary an environmental load charge was introduced in 2003 covering pollution released to air, water and soil. The charge is paid by those installations subject to permits and does not apply to households. The charge was introduced gradually, so 40% of the calculated charge was applied in 2004 and 2005, 75% in 2006, 90% in 2007 and 100% in 2008 and onwards. An extra penalty is charged for exceeding limits set out in air quality regulation. Yet, there is a possibility of a 50% reduction in the rates in cases where the installation of abatement equipment has commenced.

Since 2006, Poland has applied a hybrid air pollution charge scheme established by the Environmental Protection Act of 2001 that covers over 60 specific polluting substances: a basic charge is paid on all emissions below an emissions limit and a penalty charge – up to 10 times higher than the basic charge – is paid on remaining emissions above the limit. The charges are paid semiannually to the respective regional authority and originally were earmarked to county and municipal environmental funds. However, these funds were then abolished at the end of 2009.

In Slovakia, air pollution charges are currently set by the 1998 Act on Air Pollution Charges covering a range of core pollutants and four groups of other harmful substances. Basic rates are set for emissions up to permitted emission concentration limits while non-compliance rates (3-4 times higher than basic rate) are levied upon emissions exceeding emission limits. The revenues from the charge had an increasing trend, peaking in 2006 and then reversed and recorded its lowest revenue in 2010.

Table 2. Nominal rates of air pollution charges (in EUR/ton)

	Sulfur dioxide	Nitrogen oxides	Particulates/ dust	Carbon monoxide	Carbon dioxide	Organic carbon	Heavy metals
Bulgaria[a]	0–20	80–130	40–60			2,550	15,320 (lead) 45,950 (cadmium)
Czech Republic	40	32	119	24		79	791
Estonia	51	84	51	5	2	84	1,228
Hungary	180	430	110				
Poland	120	120	80-330[c]	30	0.07	30	1,280-85,300
Slovakia	64	48	160	32		128	1,280/640[b]

Notes: rates valid for year 2010, except in Bulgaria for year 2008.

* non-compliance fees, ** class 1 / class 2 substances, † lower rate applies to particulates from fuel combustion.

Sources: OECD/EEA database on instruments used for environmental policy and natural resources management (http://www2.oecd.org/ecoinst/queries/).

ENERGY TAXATION

Taxes on energy products used for heating (mainly coal and natural gas) and electricity have only been introduced in the majority of new EU members from the CEE region in the process of implementing EU law, particularly the Energy Taxation Directive.[4] Prior to implementation of this directive, energy products were taxed primarily for use as propellants and only a few of them were also taxed for use as heating fuels (e.g. fuel oil and LPG). Since the directive establishes obligatory tax exemption for fuels used for electricity production,[5] electricity taxation is only of interest to us when we focus on the internalization of external costs from electricity generation.

Almost all new EU members were allowed an exemption for taxation of electricity so as to alleviate the impact on price stability, on-going economic transition, low income levels, and limited ability to offset additional tax burdens.[6] In practice, only Hungary applied for the tax exemption at the time of accession. Poland was granted a transitional period until 2006 to align their electricity taxation regime to the Community framework. Both the Czech Republic and Slovakia introduced electricity taxation in 2007 (effective from January 2008 and July 2008, respectively). Estonia was granted a transitional arrangement until January 2010 for converting input electricity taxation into output taxation. In Slovakia the tax was originally set below the minimal rate prescribed by the Directive (0.5 and 1 €/MWh for business and non-business use, respectively) but the rate was doubled to 1.3 €/MWh in January 2010. Bulgaria was granted a transitional period for the application of the minimal excise duty rates for most energy products until January 2010 in the Accession Treaty, currently the rate is set equal to the Community minimum level. We highlight that the rate of electricity tax is in general quite low, representing only about 1% of the pre-tax electricity price. Only in Poland and Estonia are the rates levied on business consumption slightly higher and represent less than 6 to 8% of pre-tax prices.

The relatively numerous facultative tax exemptions provided for in the Directive open doors for many differences in electricity taxation among countries. One such example is a tax exemption for electricity consumed in households as employed in Bulgaria and Slovakia. None of the six countries differentiate taxes between business and non-business use, in contrast to a common practice in the majority of old EU member states aimed at alleviating the possible competitiveness burden of comparatively higher tax levels. Another difference relates to the treatment of electricity from renewable sources. While in some countries renewable electricity is exempted from electricity taxes (Czech Republic and Poland), other countries do not endorse this option (Estonia, Hungary and Slovakia). [7]

Table 3. Electricity taxation and pre-tax prices of electricity (in € per MWh)

	Business use		Non-business use	
	Tax rate	Pre-tax price	Tax rate	Pre-tax price
Bulgaria	1.00	59	1.00*	69
Czech Rep.	1.11	111	1.11	119
Estonia	4.47	59	4.47	68
Hungary	1.09	94	1.09	128
Poland	4.71	79	4.71	98
Slovakia	1.32	128	*	135

* zero rate/exemption of electricity used by households.

Source: Energy taxes are from Excise duty tables published by European Commission Directorate General Taxation and Customs (January 2011). Prices are taken from OECD/IEA Energy Prices and Taxes, Quarterly Statistics, Second Quarter 2011.

RENEWABLE ENERGY SUBSIDIES

In addition to emission charges and electricity taxes, price-based support instruments for renewable sources funded from surcharge to the electricity price are also considered an internalization measure as long as they favor technologies with lower external costs per unit of electricity produced compared to their fossil-based counterparts (Longo & Markandya, 2005). However, Sandmo (1975) argues that *the fact that a commodity involves a negative externality is not in itself an argument for taxing other commodities which are complementary with it, nor for subsidizing substitutes*, hence charging the costs of subsidizing renewable electricity production in electricity price does not justify internalization even if the level of the subsidy is based on the difference between external costs associated with fossil fuel technology and renewable energy alternatives.[8] Furthermore, in some instances the subsidy exceeds the difference in the external costs between renewable electricity production and its fossil-based counterpart, which is neither economically effective nor environmentally efficient.

We account only for subsidies in the form of feed-in tariffs that are now used in all but one country of interest to us, and the quota obligation system with tradable guarantees of origin as is used in Poland.

Similarly to the divergent uses of electricity taxes, there are some differences in the use of feed-in tariffs. In Bulgaria a feed-in tariff was introduced in 2003 and substantially reformed in 2007. Priority access to the grid and a purchase obligation in respect to renewable energy is now mandated. The State Energy and Water Regulatory Commission sets annual preferential prices. The additional price for green energy charged on top of the electricity price is 0.00372 leva/kWh (1.9 €/MWh) according to CEZ Bulgaria data.

In the Czech Republic the 2005 Act on Promotion of Use of Renewable Sources introduces two different support schemes for renewable electricity production: feed-in-tariffs (guaranteed purchase price) and a green bonus (premium); both are set annually by the Energy Regulatory Authority. In principle, renewable electricity producers may opt either for the feed-in tariff with a fixed price for 15 years or a combination of the market price of electricity and an entitlement for a green premium. Since the latter option does not profit from the guaranteed purchase of electricity, the combined market price and green premium should be higher than the feed-in tariff. Delayed governmental response to decreasing investment costs of photovoltaic panels caused a massive boom in 2009 leading to a substantial increase in a RES support surcharge to 370 CZK/MWh (15.15 €/MWh) in 2011 that translated into about 5% increase in the consumer price of electricity.

In Estonia all electricity consumers have to pay a fee for subsidizing renewable energy and combined heat and power generation. The additional subsidy for the support and purchase obligation of renewable electricity has been set to 6.1 €/MWh in 2011 by the transmission system operator Elering.

In Hungary, there is a similar subsidy for renewables and co-generation charged on top of electricity price. In the first half of 2010 the specific support – i.e. the difference of the subsidized price and market price without any support – amounted to 12.25 HUF/kWh (44.7 €/MWh) according to the Hungarian Energy Office. When recalculated over total net electricity consumption, about the resulting price is 2.5 HUF/kWh (9.1 €/MWh).

In Poland tradable quotas are used for the support of renewable energy, and according to Vattenfall 2010 data the price for the mandatory buy-out of RE adds about 5.35 €/MWh to the price of electricity for households.

In Slovakia, the Regulatory Office for Network Industries sets fixed purchase prices for a period of 12 years from the date the installation begins to operate. Slovakia has also seen a major boom in PV generators and the top-up amount for RES support (together with support for domestic coal extraction and CHP) paid on top of the electricity price has been raised to 14.85 €/MWh for 2011.

Estimating External Costs

The methodology adopted in this paper is based on the ExternE impact pathway analysis (IPA) and takes into account the most recent methodological improvements achieved in recent EU-funded research projects (Bickel & Friedrich, 2004, Diakoulaki et al., 2007). The IPA is an analytical procedure examining the sequence of processes through which emissions of a particular source of pollution result in environmental damage. Relevant impacts and external costs are calculated on a marginal basis by considering the incremental burden by the analyzed emission source, which is determined with regard to both location and type of energy technology.[9]

The IPA procedure has been incorporated into the EcoSenseWeb software tool (Preiss & Klotz, 2008), an integrated atmospheric dispersion and exposure assessment model.[10]

The atmospheric emissions are linked via air transport models, modeling the changes in ambient concentration and exposure-response relationships to a range of impacts on a local, regional as well as hemispheric level.

When calculating the impacts for each power plant, we distinguish several impact categories:

- Damage caused to human health, crops and building materials
- Impacts of climate change attributable to the emission of greenhouse gases
- Ecosystem degradation due to acidification and eutrophication
- Health impacts associated with micro pollutants.

To assess the physical impacts, one has to establish a link between a change in ambient air concentration of a pollutant and physical impacts. Effects on human health, crops and building materials are estimated by using concentration-response functions,[11] impacts associated with climate change and ecosystems are quantified by using generic monetary values per unit of pollutant release or area of land use changed.[12]

In currently quantifiable external costs, the two most important impacts are associated with climate change and human health. Apart from climate change impacts, the external costs are dominated by the impacts on human morbidity and mortality. Morbidity impacts include, for instance, new cases chronic bronchitis, hospitalizations for cardiovascular and respiratory illnesses, lower respiratory symptoms, asthma exacerbations, or work loss days. Particulates, ozone and micro-pollutants are also associated with premature mortality, quantified in years of life lost. Hurley et al. (2008) provide the most recent review of the concentration-response relationships relevant to health impacts.

Physical impacts are then translated into monetary terms by using appropriate valuation techniques. In the current version of the ExternE method damage to crops, building materials and biodiversity is quantified by using the market price of crops, maintenance and replacement costs, and restoration cost, respectively. Monetized health effects on morbidity takes into account the medical treatment cost associated with illness treatment, loss of productivity due to work absenteeism and willingness to pay for avoiding adverse health outcomes. The effect on premature mortality is quantified by multiplying the estimated years of life lost with the value of life year (see Desaigues et al., 2011). Quantification of climate change impacts in the ExternE methodology relies on mitigation or abatement costs, although they can serve as a proxy for environmental external costs only. The value of 19 $€_{2000}$ per ton of carbon dioxide equivalent has been used as a recommended default value for these impacts for about the last 15 years and is used in our external cost assessment.

Assessment of Internalization

Using ExternE methodology, the total external costs for each reference power plant were calculated using EcoSenseWebV1.3. Primarily, their magnitude is dependent on the annual electricity production and fuel used. The overall external costs range from 0.1 million € (Hungarian oil-fired power plant) to 2,290 million € (Polish lignite-fired power plant) per year. Figure 2 shows marginal external costs for the analyzed reference energy systems expressed in eurocents (€c) in 2010 per 1 kWh of electricity produced. The plant-specific external costs range from slightly more than 1.3 €c per kWh generated in a power plant burning natural gas to 7.7 €c for a plant burning brown coal.

The external costs attributable to coal-fired power plants also vary across specific technologies given by the type of end-of-pipe technology: boiler, burning process or coal fired. For instance, the external costs attributable to the power plants that combust low quality lignite in Poland (7.75 €c) and hard coal in Bulgaria (7.15 c€) are larger than the externalities of a lignite-fired Czech power plant (6.81 c€). An oil shale-fired power plant in Estonia is also characterized by high external costs that are around 6.63 €c per kWh. The external costs of generating electricity in gas-fired power plants are four to six times lower than the externalities of coal-fired plants. Hungarian and Czech natural gas operating power plants cause external costs of 1.96 c€ and 1.37 c€, respectively. Interestingly, the

Hungarian oil-fired power plant outperforms coal fired generators, with the external costs around 4.33 €c per kWh.

Figure 2. Marginal External Costs (in €c/kWh of 2010)

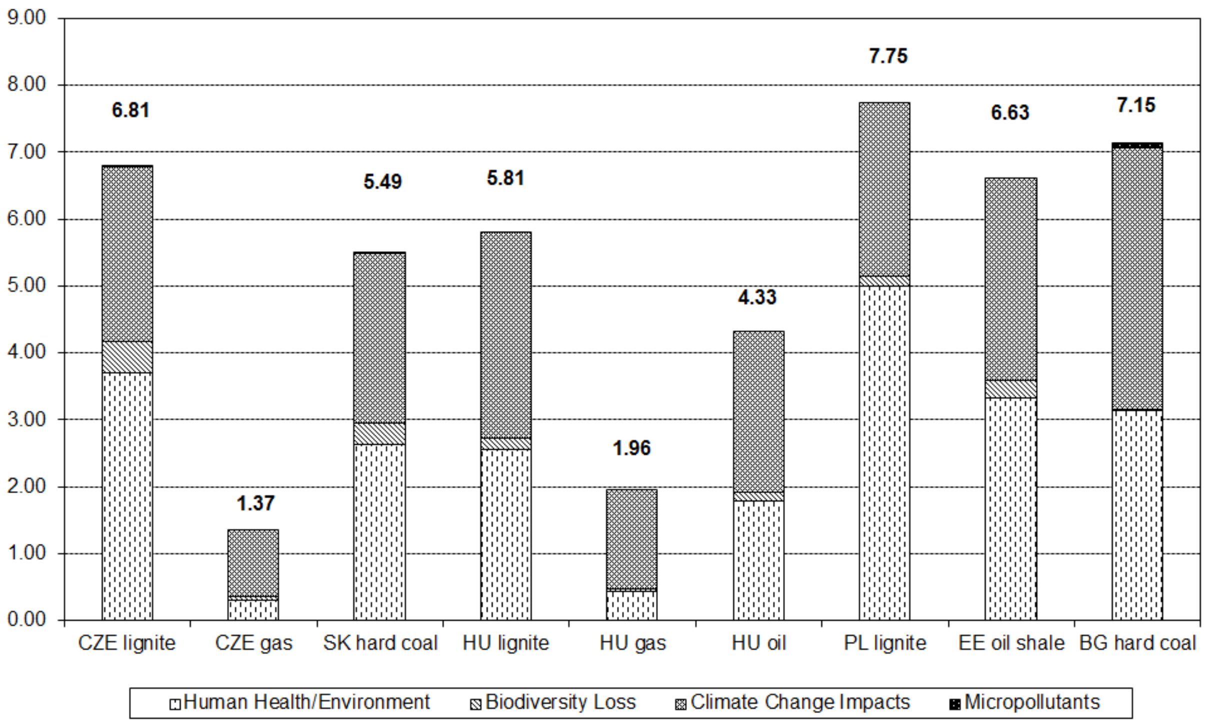
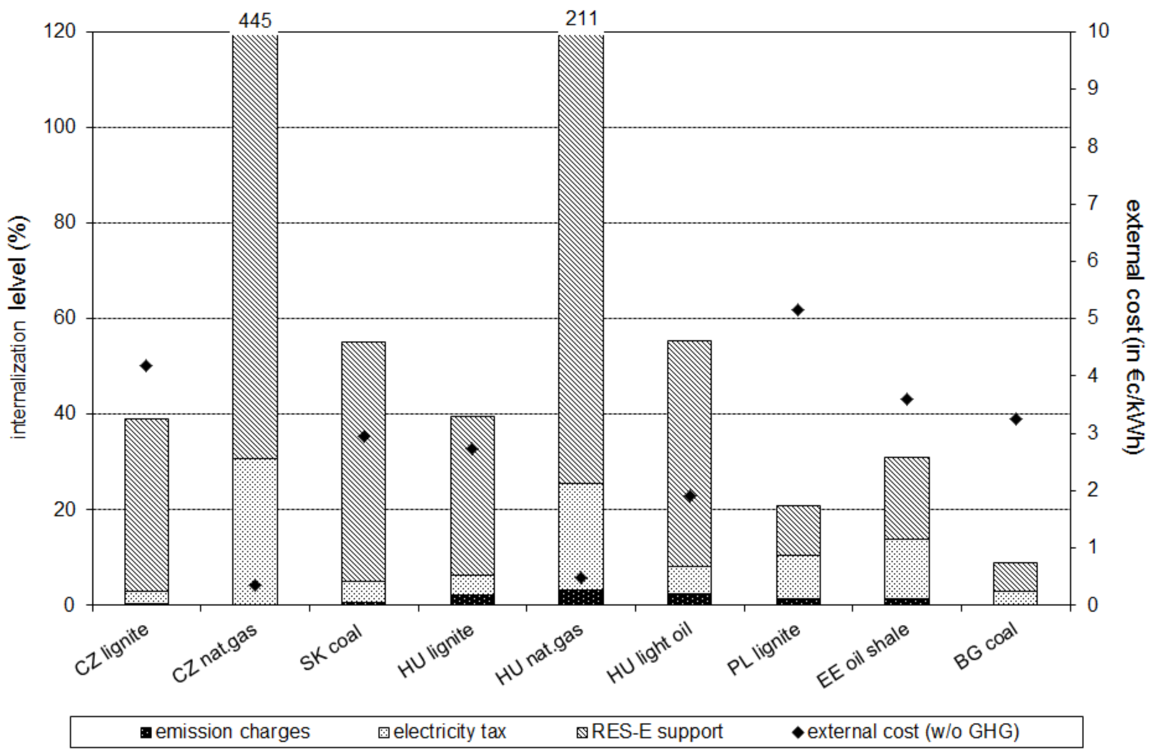


Figure 2 also provides a breakdown of external costs according to the impacts on human health, impacts related to climate change and impacts on biodiversity loss due to acidification and eutrophication. Climate change impacts contribute a substantial part to the total magnitude of damage. In the case of natural gas-fired plants this damage is a dominant part of total external costs as it covers almost 75% of the total damage. Contrary to this, the climate change impacts account for 35% of the damage caused by lignite-fired power plants. The second major part of external costs is attributed to impacts on human health, the proportion of which ranges from 23% (Czech gas-fired plant) to 55% (Czech lignite-fired plant). Of human health impacts, mortality impacts outweigh effects on morbidity: mortality accounts for up to 66% of damage to human health. Other significant impacts are damage to biodiversity, which accounts for 2-7% of the total impacts. The magnitude of impacts on material buildings and crops, and human health due to micro-pollutants is insignificant: they are in total below 1%.

A straightforward approach for assessing the internalization of external costs is a comparison between estimated external costs and price-based instruments levied upon electricity generation on either the input or output side.[13] In spite of its relative simplicity, numerous limitations still arise from the limited scope of the assessment and data compatibility. One particular problem relates to energy taxation of combined heat and power generation due to different taxation regimes for electricity and heat; in this case external costs need to be allocated to each commodity. This is only the case for one of the assessed reference power plants, and its heat generation is in fact almost negligible compared to the volume of electricity generation.

Figure 3 provides a comparison of external costs (dots and the right-hand vertical axis) and the rate of their internalization based on pollution charges, electricity taxes and cross-subsidies for renewable electricity (bars and the left-hand vertical axis) for reference power plants operating in the six analyzed CEE countries.

Figure 3. External Costs and their Internalization



Notes: the internalization level refers to the ratio of internalization measures (charges, taxes and subsidies) to external costs of its respective facility.
RES-E – electricity from renewable sources
Source: own calculations

The resulting picture gives mixed evidence on internalization levels at different power plants in different countries and particularly on the role of renewable energy subsidies. Overall, the level of internalization by the three market-based instruments ranges from less than 9% in the case of the Bulgarian coal fired power plant to about 55% in the Slovak coal and Hungarian light oil powered power plants and a huge over-internalization in both natural gas powered power plants considered.

The first conclusion evident from the graph is that emission charges (peaking at a level of 3% internalization in Hungarian natural gas propelled power plants) play only a marginal role with respect to the internalization of the external costs conforming to the premise of the revenue raising objective rather than as an instrument to stimulate the emission reductions. Electricity taxes on the other hand have relatively varied effects, most notably in cases of natural gas propelled generators, making 30% and 22% internalization for Czech and Hungarian power plants, respectively, but only a modest effect in all the coal burning power plants.

In contrast, generous subsidies for renewable energy (particularly in the Czech Republic, Slovakia and Hungary until 2010) provided mainly through feed-in-tariffs and their funding via mounting surcharges on the price of electricity have encouraged externality internalization. Moreover, in the two power plants we analyzed the combined effect of these three instruments leads to substantial over-internalization of the external costs.

Interestingly, a two- to four-times over-internalization is encountered in the sources with the lowest external costs. This is a consequence of flat rates of electricity tax and renewable support surcharges, where the respective rate is related to electricity output (i.e. levied per kilowatt hour) but not to the actual level of emissions. If there were no command-and-control requirements in place for the operation of power stations such arrangements might favor emission-intensive fuels and technologies as long as the marginal abatement costs of pollution exceed the actual emission charges.

Conclusions

In this paper a bottom-up approach to quantification of air pollution externalities is used to show that market-based instruments are not very effective in internalizing these external costs in six CEE countries. When marginal external costs associated with air pollution are compared with rates of environmental taxes and pollution charges we find that the level of internalization is fairly low for the reference fossil-fuelled power plants in all six countries ranging from 3% for coal- and lignite-fuelled plants to 31% for gas-fuelled plants. The picture improves if a cross-subsidy for renewable electricity is accounted for but internalization level is still well below air pollution related external costs, between 9 to 55% for coal- and oil-fired power plants. We find, however, that in the case of gas-fired power plants these three instruments altogether regulate more than the actual damage caused. We also highlight that electricity generation from burning natural gas is associated with four to six times lower damage than other fossil-based power plants.

There are two obvious reasons why this situation occurs. First, there is an apparent lack of political will to substantially increase environmental pollution charges to a level that would correspondent to the damage caused by the emission released. Except in Estonia, where environmental charges are continuously increased year after year, setting higher environmental charges is generally deemed as a measure that would affect competitiveness of producing sectors that still represent significant portions of gross domestic product. Consequently, emission charges are generally deemed to be ineffective in terms of motivational effect in the six CEE countries. It is no surprise that such levies give little stimuli to further emission reductions and do not fulfill a potential for dynamic efficiency, an attribute favoring market-based instruments over their command-and-control counterparts.

In the Czech Republic, a simulation using the macro-econometric model E3ME shows that the abolishment of a charge on SO2, NOx, particulate matters and VOC emissions released from large stationary emission sources would have an insignificant effect on GDP and employment. On the other hand, stricter regulation need not necessarily have negative effects on the economy, although the structure of the economy and fuel mix may change significantly as documented by Ščasný et al. (2009). Such a policy that would significantly increase charges on emissions of particulates, SO_2, NOx and VOCs in the Czech Republic (compared to rates referred in Table 2) would only slightly increase the level of GDP to 0.1% compared to business-as-usual.[14]

Simultaneously, this strict policy would induce a change in the structure of the whole economy, reduction of total energy use and changes in the fuel-mix, which would all contribute to emission reduction. Such general equilibrium effects of stricter policy, which would internalize the external costs further, would result in lower external costs and consequently increase the magnitude of the internalization rate. This would however necessitate an extension of the current analysis to a general equilibrium framework as an optional future research focus.

Secondly, the majority of power plants currently in use do not run on state-of-the-art technologies. This means that the external costs per unit of electricity produced are substantially higher as compared to the best available technologies. The gradual replacement of older installations (which is expected to take place in the next decade) will considerably increase the internalization of external costs by existing instruments.

In addition, the fuel mix composition is of particular concern here. Estonia and Poland depend heavily on a single fossil fuel (coal and lignite in Poland, oil shale in Estonia) which is their only abundant domestic fossil energy source, but also one of the dirtiest and most carbon intensive. While less dependent on a single source, Bulgaria, the Czech Republic, Hungary and Slovakia still rely in part on lignite combustion usually as the only available domestic fossil energy source.

Our analysis of the internalization of external costs deals only with airborne pollution, while energy generation may also cause other types of negative external effects, such as damage from radionuclides or accidents, intrusion and loss of landscape amenity or various effects related to downstream and upstream processes. In addition, climate change mitigating policies (e.g. the cap-and-trade system) would have most likely ancillary effects on airborne emissions. Research looking into such inter-linkages would demand a more integrated impact assessment approach to make it possible to attribute the impacts to respective policies, but at the same time would most likely shift the internalization level downwards.

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[1] The Czech Republic, Estonia, Hungary, Poland, and Slovakia joined the European Union in May 2004; Bulgaria in January 2007.

[2] One specific exception is the Estonian charges on oil-shale mining, mining wastes (12 EEK/ton) and oil-shale ash (15 EEK/ton), which represented about 60% of environmental levies paid in the energy sector.

[3] Poland and Slovenia also charge for CO_2 emissions.

[4] Council Directive (EC) 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity, [2003] OJ L 283/51.

[5] See article 14 (1)(a) of the Directive.

[6] See Council Directive (EC) 2004/74/EC of 29 Apr 2004 amending 2003/96/EC as regards to the possibility of certain Member States to apply, in respect to energy products and electricity, temporary exemptions or reductions in the levels of taxation, [2004] OJ L157/87.

[7] However, in Slovakia if the electricity is delivered directly to the final consumer or consumed by the producer a tax exemption also applies.

[8] Interestingly, European Commission Guidelines for state aid in environmental protection (OJ C 82, 1.4.2008, p. 1) explicitly allows that operation aid in production of renewable energy may be granted on the basis of external costs avoided (see point 161 of the Guidelines) but this option was never put in practice.

[9] An alternative approach to calculating pollution damage based on material-flow analysis was developed by Muller, Mendelsohn & Nordhaus (2011).

[10] The latest version EcoSenseWeb 1.3 was developed by the Institute for Rational Use of Energy (IER) at University of Stuttgart in EC funded projects NEEDS and CASES. The model's homepage is http://ecosenseweb.ier.uni-stuttgart.de/.

[11] In the case of pollutants such as particulate matter or sulfur dioxide, the effect is assessed through the concentration-response functions, while the effect of micro-pollutants is evaluated through the exposure-response functions, see e.g. Rabl (1998) for a more detailed overview.

[12] The change of biodiversity is estimated with the potentially disappeared fraction concept.

[13] To allow for comparison between external costs expressed in euros at the 2000 price level and environmental taxes and charges (which mostly refer to the year 2010), we recalculated external costs to euros at the 2010 price level using overall harmonized indices of consumer price (HICP) changes for EU-27, using a multiplication of 1.26.

[14] Ščasný et al. (2009) specifically used the macro-econometric model E3ME to assess the impact of increases in the rate of charges levied on particulate matter by 32-times, on sulfur dioxide by 16-times, on nitrogen oxides by 40-times and on volatile organic compounds by 48-times allowing simultaneously for carbon taxes with a rate as predicted by the PRIMES model. These new emission charge rates correspond to the level required to reach marginal shadow prices as derived by the GEM-E3 CGE to meet the National Emission Ceiling and to comply with the climate-energy 2020 package (Van Regemorter, 2008).

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Vojtěch Máca is a research fellow in the Department of Environmental Economics and Sociology of Charles University Environment Center in Prague. He received his PhD in public and environmental law from Charles University. His area of specialization is law and economics of environmental externalities, including environmental policy analysis, external cost assessment and non-market valuation.

Jan Melichar is a research fellow at the same Center. He obtained his PhD in economic policy from the University of Economics in Prague. His research mainly deals with empirical analysis in the field of environmental economics. His research interests include external cost assessment, environmental cost-benefit analysis, non-market valuation and recreation demand analysis.

Milan Ščasný is a research fellow at the same Center. He obtained his PhD in economic theory from Charles University in Prague. His research activities cover health benefit valuation, non-market valuation, household consumption and demand, impact assessment (particularly distributional impact analysis), and external costs assessment.