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External costs of electricity generation options in Lithuania

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ABSTRACT

This article deals with external cost of electricity generation in Lithuania. The external costs of electricity generation are the most important environmental criteria shaping decisions within the electricity system. External costs of electricity generation were calculated based on ExternE methodology for Lithuania during EU (European Union) Framework 6 project Cost Assessment for Sustainable Energy Systems (CASES). The article presents the methodology and results of external costs of electricity generation in Lithuania. The assessment of external costs provided that future energy policy should be oriented towards the renewable energy generation technologies having the lowest external costs. External costs for electricity generation technologies were analysed in terms of external costs categories, electricity generation technologies life cycle stages and time frame 2010–2030.

1. Introduction

The sustainable energy development is the key issue of national and international policies [1–3]. Efforts towards a sustainable energy system are progressively becoming an issue of paramount importance for decision makers. Environmental sustainability constitutes the main energy policy objectives for a sustainable energy system. Implementation of new energy technologies is a key mean towards a sustainable energy system. The environmental sustainability of electricity generation technologies can be addressed by integrating external costs of electricity generation in decision making. The electricity generation technologies should be selected by taking into account life time external costs.

External costs for electricity are those that are not reflected in the price of electricity, but which society as a whole must bear. For example, the biggest damage to human health is caused by emissions of particulate matter, SO_2, NO_x and NMVOC [4]. There are also costs associated with non-health impacts. SO_2 is the main pollutant of concern for building-related damage, though ozone also does affect certain materials. The secondary pollutants formed from SO_2, NO_x and NMVOC also impact on crops and terrestrial and aquatic ecosystems.

The external costs arising from the environmental impact of electricity production are significant in most EU countries and reflect the dominance of fossil fuels in the generation mix. In 2005–2010 the average external costs of electricity production in the EU were about 6 Eurocent/kWh [5]. The externalities also vary between the EU Member States, as a result both of the fuel mix and location. Higher damages typically occur from emissions in countries in Western Europe because of the large population affected. Countries with lower mean externalities are Austria, Finland and Sweden, reflecting their low population density (in the two latter) and greater use of nuclear and renewable energy and, in particular, hydropower. Despite progress, these external costs are still not adequately reflected in energy prices. Consumers, producers and decision makers do not therefore get the accurate price signals that are necessary to reach decisions about how best to use resources [5]. Table 1 presents external costs of classical pollutants for EU member states [6]. The costs were recalculated in 2010 prices to adjust inflation.

Damages from climate change, associated with the high emissions of greenhouse gases from fossil fuel based power production, also have considerable costs. However, given the long-time scales involved, and the lack of consensus on future impacts of climate change itself, there is considerable uncertainty attached to the damage costs. The external costs of CO_2emissions must thus be interpreted with care [7]. There is no single value and that the range of uncertainty around any value depends on ethical as well as economic assumptions [7]. The damage factors for CO_2 used in this factsheet range from 22.5 EUR/t CO_2 (low estimate, based on ExternE-Pol) and 95 EUR/t CO_2 (high estimate, based on [7] recalculated in 2010 prices. These two values are common to all countries.

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

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Table 1
External costs of pollutants in EU-15, EUR 2010/t.

	External costs (EUR 2010/t)		
	SO_2	NOx	Particulates
Denmark	4841–6826	5310–7655	5488–10,792
Sweden	3816–4549	3168–3789	4423–6217
Finland	1663–2409	1379–2247	2169–4227
Germany	2914–22,161	17,720–24,447	15,381–37,909
United Kingdom	9758–16231	9287–15562	12952–37103
Ireland	4533–8581	4452–4857	4533–8767
Belgium	18,438–19,656	18,661–19,907	39,742–39,725
Netherlands	10,046–12,274	8872–9852	24,295–27,248
Austria	14571	27199	27199
Portugal	8030–8487	9674–10,624	9010–11,260
Spain	6897–15,515	7530–19,519	7153–32,785
France	12,143–24,771	17,453–29,142	9875–92,283
Greece	3202–12,680	2008–12,625	3261–13,402
Italy	9228–19,428	7447–21,965	9228–33,513
EU average	7859–13,438	10014–14,956	13634–27,316

(<0) to over 400 USD per ton CO_2 currently emitted [7]. R. S. Tol constructed a probability density function of published estimates [8]. 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. The literature reports annual increases in the marginal costs of CO2 emissions range between 1 and 2 percent [9,10]. 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 [11,12]. The social cost of carbon is the social cost of the emission of one tonne of CO2 at a particular date; hence it is another word for the marginal (social) cost of 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. The Stern Review [13] assessed the economics of moving to a low carbon economy, focussing 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. 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 R. S. Tol's probability density function [10]. 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.

Lithuania has started challenging project – construction of new nuclear power plant however there are debates between policy makers and the strong opposition from various non-governmental organizations considering nuclear as environmentally dangerous generation option. The comparison of external costs of various electricity generation options in Lithuania would allow assessing and ranking possible future electricity generation options based on their environmental impacts.

The aim of the paper is to compare external costs of the main electricity generation technologies for Lithuania and to define the technologies having the lowest external costs. The main tasks of the paper are to present methodology for assessment of external costs of electricity generation; to select future electricity generation technologies relevant to Lithuania; to define external costs of electricity generation options and to rank electricity generation technologies based on external costs.

2. Methodology for assessment of external costs in electricity sector

During EU Framework 6 project CASES external costs of electricity generation were assessed for all EU member states for 2010–2030. External cost of electricity generation (in EuroCents/kWh) are calculated by multiplying the average height of release values of unit of emission for classical air pollutants (2005 Eurocent/kg) times the quantity of emission for unit of electricity generated (kg/kWh).

Marginal external costs for classical air pollutants are calculated for CASES project by applying updated *EcoSenseWebV1.2* tool [14].

To estimate external costs by transforming impacts that are expressed in different units into a common monetary unit, the *ExternE* methodology was adopted [15–17]. The methodology for assessment of external costs was developed and updated during EU projects: ExternE, NewExt, ExternE-Pol, DIEM, ECOSIT, INDES, MAXIMA, NEEDS and CASES.

The principal stages of the ExternE methodology are the following [16]:

- Definition of the activity to be assessed and the background scenario where the activity is embedded. Definition of the important impact categories and externalities.
- Estimation of the impacts or effects of the activity (in physical units). In general, the impacts allocated to the activity are the difference between the impacts of the scenario with and the scenario without the activity.
- Monetisation of the impacts, leading to external costs.
- Assessment of uncertainties, sensitivity analysis.

The impact categories which are addressed using the ExternE methodology and that are analysed in the full costs assessment are the environmental impacts (on human health, crops and loss of biodiversity) the damage to materials and the global warming impact. The approach used to quantify environmental impacts is the *Impact Pathway Approach* (IPA). The principal steps can be grouped as follows [17,18]:

- Emission: specification of the relevant technologies and pollutants emitted by a power plant at a specific site, for the whole life cycle, which is from construction to dismantling, including fuel extraction and transportation;
- Dispersion: calculation of increased pollutant concentrations in all affected regions, using models of atmospheric dispersion;
- Impact: calculation of the cumulated exposure from the increased concentration, and calculation of impacts (damage in physical units) from this exposure using an exposure-response function;
- Cost: valuation of these impacts in monetary terms.