External costs and the Belgian energy system, Johan Albrecht

An externality is present when an action by an individual producer or consumer affects other parties, without payment or compensation for the cost or benefit affecting them. An activity with a cost externality imposes net costs on other and non-compensated parties. Hence, the external costs of energy systems are those costs for society that are not covered by the producers and consumers. Energy and electricity production externalities are also termed input externalities since the external cost is directly related to the choice of inputs.
The presence of externalities is a form of market failure, meaning that the market allocation is not efficient. With the internalization of external costs, the production as well as the consumption side of the economy will adapt to new relative price levels.

1. Damage categories and methodology

The economic valuation of external costs starts with a clear identification of the involved damage categories. The most important damage categories in the literature on external costs of energy and transport are:

1. human health – *mortality*: pollutants/burdens leading to a reduction of life expectancy ($PM_{10}$, $SO_2$, $NO_X$, $O_3$), cancers (benzene), accidents risk, etc.
2. human health – *morbidity*: restricted activity days ($PM_{10}$, $O_3$), congestive heart failure ($PM_{10}$, CO), asthma attacks ($O_3$), etc.
3. building materials: ageing of galvanised steel, limestone, mortar, sand-stone, etc
4. crops: yield changes for wheat, barley, rye, oats, etc
5. global warming: global effects on mortality, morbidity, agriculture, etc.
6. amenity losses: losses due to noise exposure, landscape pollution, etc.
7. ecosystem: acidification and eutrophication
8. congestion costs: time losses in transport systems

To calculate external costs of energy and transport emissions in the European Union, the *impact pathway* approach was developed within the ExternE project series. The impact pathway assessment is a bottom-up[1] approach in which environmental benefits and costs are estimated by following the pathway from single *source* emissions via quality changes of air, soil and water to physical impacts (e.g. increased emissions). In this approach, a precise reference scenario without the activity under analysis – here energy and transport activities - provides the background concentration of the pollutants under analysis. The background concentration is a crucial factor for pollutants with non-linear chemistry of non-linear dose-response functions. The additional emissions from the activities under analysis are then introduced in the model by dispersion functions and can lead to increased concentrations at receptor sites. Dose-response or exposure-response functions are then used to derive differences in physical impacts. Since air pollutants are transformed and transported, not only local damages are considered under this approach. For human exposure to heavy metals and some important organic substances (e.g. dioxins) which accumulate in water and soil compartments and hence lead to a significant exposure via the food chain, additional models are used. Finally, a monetary valuation is attached to these physical impacts (e.g. human health costs). For some of the impacts (crops and materials), market prices can be used. For

[1] Top-down approaches make use of highly aggregated data to estimate costs of particular pollutants: estimated national damages are divided by total pollutant depositions to produce a measure of physical damage per unit of pollutant. The approach has been criticized mainly for not being capable of taking the site specificity of certain types of impacts into account.

non-market goods (especially damages to human health and amenity losses), evaluation is only possible on the basis of the willingness-to-pay or the willingness-to-accept approach, both based on individual preferences. The latter approaches have significant drawbacks since respondents might provide biased answers for various reasons.

*Global warming damages?*

This methodology is however not appropriate for damage categories with very high uncertainties such as damages from global warming. To integrate global warming damages into assessments of current energy and transport externalities, estimated future climate change damages from greenhouse gas emissions first need to be discounted to be added to the external costs of other pollutants. This is essentially a normative exercise in which judgements need to be made about the discount rate, the value of a statistical life and the magnitude of higher order effects. These normative debates are still open. Therefore, most assessments present climate change damage costs with an extended sensitivity analysis. In the latter excercises, discount rates typically range from 0% to 5% (with 1% and 3% as most frequently used values). With a 3% discount rate, climate damages that will materialize after 2075 have a negligible current value. The use of a commercial discount rate leads to negligible current costs for climate change damages that will be experienced after the year 2035.

To circumvent these and other normative issues, the use of avoidance costs to reach agreed environmental aims has been presented as an alternative second best approach. This approach implicitly assumes that policymakers with perfect foresight are able to set welfare-maximising environmental targets. For global warming, a shadow price (i.e. a virtual taxation rate on greenhouse gas emissions) for reaching the Kyoto reduction targets is typically used in Europe. This shadow price is calculated to realize the reduction target of the EU-15 and not for each country separately. Otherwise several countries with very challenging reduction targets would face enormous climate damage costs. In the most recent analyses of external costs of energy technologies in Europe, this shadow price or avoidance cost has been estimated at € 19 per ton of $CO_2$. Based on this estimate, we find that in a country like Germany the external cost from greenhouse gas emissions largely exceeds the sum of all other external costs for coal, lignite and gas plants.

2. Results: electricity production

Table I presents an overview of recent external cost figures for electricity production in the EU. The presented figures include the global warming cost of € 19 per ton of $CO_2$.

**Table I – External costs of electricity production in €cent per kWh**

| Country | Coal & lignite | Peat | Oil | Gas | Nuclear | Biomass | Hydro | PV | Wind |
|---|---|---|---|---|---|---|---|---|---|
| AT | | | | 1-3 | | 2-3 | 0.1 | | |
| BE | 4-15 | | | 1-2 | 0.5 | | | | |
| DE | 3-6 | | 5-8 | 1-2 | 0.2 | 3 | | 0.6 | 0.05 |
| DK | 4-7 | | | 2-3 | | 1 | | | 0.1 |
| ES | 5-8 | | | 1-2 | | 3-5 | | | 0.2 |
| FI | 2-4 | 2-5 | | | | 1 | | | |
| FR | 4-10 | | 8-11 | 2-4 | 0.3 | 1 | 1 | | |
| GR | 5-8 | | 3-5 | 1 | | 0-0.8 | 1 | | 0.25 |
| IE | 6-8 | 3-4 | | | | | | | |
| IT | | | 3-6 | 2-3 | | | 0.3 | | |
| NL | 3-4 | | | 1-2 | 0.7 | 0.5 | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| NO | | | | 1-2 | | 0.2 | 0.2 | | 0-0.25 |
| PT | 4-7 | | | 1-2 | | 1-2 | 0.03 | | |
| SE | 2-4 | | | | | 0.3 | 0-0.7 | | |
| UK | 4-7 | | 3-5 | 1-2 | 0.25 | 1 | | | 0.15 |

Source: European Commission (2003). External Costs. Research results on socio-environmental damages due to electricity and transport (EUR 20198), p.13

Table I shows that comparable electricity production technologies yield significant differences in external cost estimates. The analysis however confirms that nuclear and renewable energy technologies produce the lowest external costs. Of the fossil fuel based technologies, gas technologies clearly generate the lowest external costs.
The presented figures are based on the existing capital stock for each group of technologies. There are however enormous differences in efficiency between recent and old plants. The improvement of efficiency appears to be a continuous process and obsolete plants are gradually scrapped and replaced by the newest types. This explains the strong reductions in non-climate external costs – other than the external costs from greenhouse gas emissions- that have been observed over the last 15 years. While the non-climate damage cost (mainly from $PM_{10}$, $SO_2$ and $NO_X$ emissions) of a coal-fired plant built in the early 1990s was calculated at more than 10 €cents/kWh, the damage cost for the most recent coal plants slightly exceeds 1 €cent/kWh. The non-climate damage cost of the most recent gas and oil plants is 0.2 respectively 1.3 cents per kWh[2]. The results for Europe are very similar to research in the United States and other non-European countries. In the appendix, Table V presents an overview of the findings in recent bottom-up estimates of external costs from electricity production.
More detailed ExternE 1998 results for Belgium are presented in Table II. This table is based on four estimates for the global warming damage from electriticy production (low, mid 3%, mid-1% and high). The Belgian implementation of the ExternE methodology to the production of electricity leads to following conclusions:

- Under the scenario with high global warming damage, the external cost from greenhouse gas emissions is responsible for 59% of total external costs.
- The damages per ton of pollutant for $SO_2$, $NO_x$ and $PM_{10}$ are high compared to other countries because the area downwind is densely populated.
- The old coal fired power plants have very high externalities, ranging from 120 to 150 mEuro/kWh for the mid estimates for global warming; retrofitting these plants reduces externalities to 37 to 65 mEuro/kWh.
- Externalities for gas are significantly lower and vary from 11 to 22 mEuro/kWh.
- Externalities for nuclear are around 4 mEuro/kWh (based on 0 % discount rate).
- Notwithstanding the high share of nuclear in power generation, aggregated damages are high and vary from 1 to 2.8 % of GDP. The old coal fired power plants are responsible for the major share of these externalities and the foreseen retrofitting/replacement of these power plants will results in much lower aggregated damages by 2005.

[2] Van der Zwaan, B. and Rabl, A. (2003). Prospects for PV: a learning curve analysis. *Solar Energy* **74**, 19-31

**Table II- Aggregated damages for electricity production in Belgium, ExternE 1998**

| **Low** | | | | *MEuro* | | | | *mEuro/kWh* |
|---|---|---|---|---|---|---|---|---|
| | **$SO_2$** | **$NO_x$** | **TSP** | **GHG** | **other** | **Total** | % | **Total** |
| Coal and Oil | 915 | 650 | 142 | 76 | 23 | **1807** | 88% | **88** |
| Gas | 0.01 | 30 | 0.00 | 7.37 | 1.01 | **38** | 2% | **7.58** |
| CHP | 26 | 17 | 0.96 | 3.75 | 0.57 | **48** | 2% | **46** |
| Nuclear (open) | | | | 0.48 | 101 | **102** | 5% | **4.02** |
| Nuclear (closed) | | | | 0.23 | 55 | **56** | 3% | **4.02** |
| TOTAL | 940 | 697 | 143 | 88 | 182 | **2050** | 100% | **31** |
| *%* | *46%* | *34%* | *7%* | *4%* | *9%* | | | |
| **Mid-3 %** | | | | *MEuro* | | | | *mEuro/kWh* |
| | **$SO_2$** | **$NO_x$** | **TSP** | **GHG** | **other** | **Total** | % | **Total** |
| Coal and Oil | 915 | 650 | 142 | 361 | 45 | **2113** | 88% | **103** |
| Gas | 0.01 | 30 | 0.00 | 35 | 2.6 | **68** | 3% | **13** |
| CHP | 26 | 17 | 1.0 | 18 | 1.2 | **63** | 3% | **60** |
| Nuclear (open) | | | | 2.3 | 101 | **104** | 4% | **4.1** |
| Nuclear (closed) | | | | 1.1 | 55 | **56** | 2% | **4.1** |
| TOTAL | 940 | 697 | 143 | 417 | 206 | **2403** | 100% | **37** |
| *%* | *39%* | *29%* | *6%* | *17%* | *9%* | | | |
| **Mid-1 %** | | | | *MEuro* | | | | *mEuro/kWh* |
| | **$SO_2$** | **$NO_x$** | **TSP** | **GHG** | **other** | **Total** | % | **Total** |
| Coal and Oil | 915 | 650 | 142 | 922 | 47 | **2602** | 85% | **127** |
| Gas | 0.01 | 30 | 0.0 | 89 | 5.6 | **121** | 4% | **24** |
| CHP | 26 | 17 | 1.0 | 45 | 2.4 | **89** | 3% | **86** |
| Nuclear (open) | | | | 5.8 | 101 | **107** | 4% | **4.23** |
| Nuclear (closed) | | | | 2.8 | 55 | **58** | 2% | **4.20** |
| TOTAL | 940 | 697 | 143 | 1065 | 212 | **3058** | 100% | **46** |
| *%* | *31%* | *23%* | *5%* | *35%* | *7%* | | | |
| **High** | | | | *MEuro* | | | | *mEuro/kWh* |
| | **$SO_2$** | **$NO_x$** | **TSP** | **GHG** | **other** | **Total** | % | **Total** |
| Coal and Oil | 915 | 650 | 142 | 2785 | 233 | **4650** | 86% | **227** |
| Gas | 0.01 | 30 | 0.00 | 270 | 16 | **313** | 6% | **62** |
| CHP | 26 | 17 | 0.96 | 137 | 6.5 | **185** | 3% | **179** |
| Nuclear (open) | | | | 17 | 101 | **119** | 2% | **4.69** |
| Nuclear (closed) | | | | 8 | 55 | **64** | 1% | **4.60** |
| TOTAL | 940 | 697 | 143 | 3218 | 412 | **5411** | 100% | **82** |
| *%* | *17%* | *13%* | *3%* | *59%* | *8%* | | | |

Source: De Nocker, Torfs, Wouters (1998). ExternE implementation in Belgium. VITO

A later and more detailed analysis for Flanders concluded that external costs from electricity production in Flanders have been reduced from € 45/MWh in 1990 to € 19/MWh in 2002. This is a reduction by 58% but since total electricity production increased by 25% over the same period, the absolute reduction of external costs from electricity is 48% (from € 1654 million in 1990 to € 865 million in 2002). This reduction is mainly attributable to the reduction of $SO_2$ and $NO_X$ emissions. Coal plants are in 2002 still responsible for 74% of total external costs. Nuclear energy provides around 48% of electricity production and is responsible for 2% of total external costs. Quite obviously, a nuclear phase-out will increase total external costs significantly. Table III shows indicative external costs in 2002 (€/MWh) per technology in Flanders.

**Table III – External costs of electricity production in € per MWh (Flanders, 2002)**

| | |
|---|---|
| Coal plants without gas cleaning | 81 |
| Coal plants with gas cleaning | 32 |
| Gas plants | 28 |
| Combined cycle gas plant (STEG) | 11 |
| Oil plant | 142 |
| CHP gas (turbine) | 8.3 |
| CHP gas (engine) | 19 |
| CHP oil | 61 |
| Waste burning with energy recovery | 80 |
| Wind | 1 |
| PV | 5 |
| Hydro | 2.2 |
| Nuclear | 0.7 |

Source: Torfs, R., De Nocker, L., Schrooten, L., Aernouts, K. and Liekens, I. (2005). Internalisatie van externe kosten voor de productie en de verdeling van elektriciteit in Vlaanderen (MIRA/2005/02, April 2005)

*Projections up to 2030*

Assessments of external costs from electricity production start from current data. To estimate the evolution of external costs for the coming decades, one needs a consistent scenario to compose the future mix of energy technologies (see e.g. PP95). This scenario should start from price projections, efficiency improvement expectations (learning curves) and the adaptability of producers, consumers and investors. With respect to the adaptability parameters, the essential question is how to use the gathered information on external effects? Will policymakers use this information in an effort to internalize external effects, or will these findings simply be ignored? This is a crucial element since efforts to internalise external effects – e.g. by means of externality taxes or externality quota- will impact the evolution of future external effects.

3. Results: damage costs for transport modes

The calculation of external costs for different transport modes distinguishes passenger transport from goods transport. So far, most research did focus on air pollution costs due to passenger transport. These costs are related to the load of a vehicle to facilitate comparison between modes. The total costs result from a LCA[3] perspective and include vehicle use costs, vehicle production costs, fuel production costs and infrastructure costs. Table IV presents air pollution costs for Belgium in € per 100 pkm (passenger kilometre).
The figures in Table IV refer to marginal costs. Obviously, external costs are strongly influenced by population density as well as local climate conditions. Table VI in the appendix presents an overview of air pollution costs in Flanders for the period 1990-2002.
Air pollution costs are only part of total external costs associated with passenger transport. Other important external cost categories are accident costs, noise costs and congestion costs. Although of less relevance in the context of the ENERGY 2030 project, the latter categories are especially important for road transport. Assessments of accident, noise and congestion costs have to deal with essential uncertainties but in a detailed analysis for Germany they outweigh air pollution costs[4].

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[3] Traditional Life Cycle Analysis (LCA) involves a complete inventory of resource inputs and outputs in all steps of production and can incorporate indirect emissions

[4] Total quantifiable externalities for the German transport sector were estimated at € 33 billion in 1998, of which around one third was due to air pollution costs (including greenhouse gas external costs).

**Table IV – Air pollution costs due to passenger transport in Belgium**

| *Urban transport* | € per passenger kilometre |
|---|---|
| Brussels car (petrol) | 1.6 |
| Brussels car (diesel) | 3.85 |
| Brussels urban bus (diesel) | 1.45 |
| *Extra-urban transport* | € per passenger kilometre |
| Belgium car (diesel) | 1.2 |
| Belgium car (petrol) | 1.15 |
| Belgium coach (diesel) | 0.16 |

Source: European Commission (2003). External Costs. Research results on socio-environmental damages due to electricity and transport (EUR 20198), p.14

*Projections up to 2020/2030*

Based on the TREMOD[5] model, researchers from IFEU (Heidelberg) calculated the evolution of fuel use and emissions by the road transport sector in Belgium during the last twenty years. This analysis departed from the composition of the Belgian car park in 1980. The results from TREMOD have been validated by comparing projected energy use and emissions to the sales of fuels between 1980 and 1999. Based on the established model, a projection up to 2020 was made to assess future air quality. This projection considered future emission standards and the consequences of existing agreements between car manufacturers and the European Commission. For the period 1995-2020, the growth of individual transport was set at 30%. The total number of kilometres driven by passenger cars has increased with 80% between 1980 and today. With respect to the transportation of goods, a 50% growth was assumed. The results of the emission projections up to 2020 show a clear trend. With the exception of $CO_2$, the emissions of all pollutants decrease seriously during the considered period. Febiac concludes that the problem of air pollution caused by the road traffic will be solved by 2020. The projections of TREMOD with respect to the evolution between 2000 and 2020 are impressive: CO emissions -72%, HC emissions -77%, $C_6H_6$ (Benzene) emissions -79%, $NO_X$ emissions -66%, PM emissions -71%. The transport-related $CO_2$-emissions continue to increase. For the next twenty years an increase of 2 to 6% is expected. As a matter of comparison, the projected increase of total Belgian energy-related $CO_2$-emissions between 1990 and 2030 is + 37.2%[6].

*Implications for total external costs of the Belgian energy system*

The expected steep reduction of transport emissions not only implies a reduction of the associated air pollution external costs. The reduction of emissions also impacts future background concentration levels of important pollutants for other sectors. Since the electricity sector needs to take the background concentration level of pollutants like CO, PM and $NO_X$ as exogenous – emitted by other economic sectors-, a lower background concentration level because of reduced pollution from the transport sector implies a lower physical impact of electricity emissions. Especially with non-linear dose-response functions, the future external costs from electricity production can be significantly lowered due to the projected emission pattern of the transport sector.

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[5] Belgische federatie van de automobiel- en tweewielerindustrie (FEBIAC), "De emissies en het energieverbruik door het wegverkeer in België (1980-2020)".

[6] European Commission (2004). European Energy and Transport – Trends to 2030 (DG Energy and Transport)

## 4. Conclusions

The expertise concerning economic valuation of external costs has strongly expanded in the last three decades. Especially the external costs from electricity production have been extensively analysed in most developed countries. The most important conclusion from the presented analyses for Europe, Belgium and Flanders is the significant reduction of external costs during the last fifteen years. We observe strong reductions of especially $SO_2$ and $NO_X$ emissions. If these trends persist, the bulk of external costs will consist of climate damage costs. For the latter cost category, avoided costs or shadow prices are usually taken as a second-best proxy. The foreseen nuclear phase-out scenario will however reverse these trends. With respect to air pollution external costs from transport activities, a similar development is projected to occur in the coming two decades. These developments result from the interactions between technological innovations and regulatory requirements.

Appendix

**Table V - Result from international studies using bottom-up damage cost approach (in $cent per kWh)**

| Study | Country | Fuel | External Cost (US Cents/kWh) |
|---|---|---|---|
| ORNL and RfF (1994-1998) | US | Coal | 0.11-0.48 |
| | US | Oil | 0.04-0.32 |
| | US | Gas | 0.01-0.03 |
| | US | Nuclear | 0.02-0.12 |
| | US | Hydro | 0.02 |
| | US | Biomass | 0.20 |
| RER (1994) | US | Oil | 0.03-5.81 |
| | US | Gas | 0.003-0.48 |
| EC (1995) | UK/DE | Coal | 0.98/2.39 |
| | DE | Oil | 3.00 |
| | UK | Gas | 0.10 |
| | FR | Nuclear | 0.0003-0.01 |
| | NO | Hydro | 0.32 |
| | UK | Wind | 0.11-0.32 |
| Rowe et al. (1995) | US | Coal | 0.31 |
| | US | Oil | 0.73 |
| | US | Gas | 0.22 |
| | US | Nuclear | 0.01 |
| | US | Wind | 0.001 |
| | US | Biomass | 0.35 |
| Van Horen (1996) | ZA | Coal | 0.90-5.01 |
| | ZA | Nuclear | 1.34-4.54 |
| Bhattacharyya (1997) | IN | Coal | 1.36 |
| Faaij et al. (1998) | NL | Coal | 3.84 |
| | NL | Biomass | 8.10 |
| EC (1999) | BE, FI, FR, DE, IE, NL, PT, ES, SE, UK | Coal | 0.84-72.42 |
| | FR, DE, GR, IT, UK | Oil | 2.07-39.93 |
| | AT, BE, DK, FR, DE, GR, IT, NL, NO, PT, ES, UK | Gas | 0.26-11.78 |
| | BE, DE, NL | Nuclear | 0.02-1.45 |
| | AT, GR, IT, PT, SE | Hydro | 0.02-18.54 |
| | DK, DE, GR, NO, ES, UK | Wind | 0.05-0.80 |
| | DE | Solar | 0.05-1.69 |
| | AT, DK, FI, FR, DE, GR, NL, NO, PT, ES, SE, UK | Biomass | 0.14-22.09 |
| Maddison (1999) | UK/DE | Coal | 0.31/0.71 |
| | DE | Oil | 0.78 |
| | UK | Gas | 0.13 |

Source: Sundqvist, T. (2004). What causes the disparity of electricity externality estimates? *Energy Policy* **32**, 1753-1766

Table VI – Marginal air pollution costs from conventional pollutants (excluding greenhouse gases) in Flanders, 1990-2002, € per 100 km (constant 2002 prices)

| Vehicle type | Fuel | 1991 | 1993 | 1995 | 1997 | 1999 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|
| Passenger car | Diesel | 6.104 | 5.685 | 4.794 | 3.845 | 2.972 | 2.260 | 1.941 |
| Passenger car | Gas | 0.486 | 0.497 | 0.461 | 0.417 | 0.395 | 0.296 | 0.267 |
| Passenger car | Petrol | 0.881 | 0.853 | 0.717 | 0.638 | 0.549 | 0.430 | 0.397 |
| Motorcycle | Petrol | 1.020 | 1.047 | 1.057 | 1.083 | 1.024 | 0.911 | 0.877 |
| Light truck | Diesel | 6.694 | 6.659 | 5.783 | 4.766 | 3.778 | 2.993 | 2.627 |
| Light truck | Gas | 0.694 | 0.692 | 0.659 | 0.591 | 0.525 | 0.454 | 0.424 |
| Light truck | Petrol | 0.843 | 0.842 | 0.798 | 0.757 | 0.704 | 0.590 | 0.555 |
| Heavy truck | Diesel | 10.068 | 10.015 | 9.613 | 9.126 | 9.006 | 8.902 | 8.856 |
| Coach | Diesel | 13.158 | 12.928 | 12.083 | 10.538 | 9.481 | 8.329 | 7.595 |

Source: VITO (2003), in De Ceuster G. (2004), Internalisering van externe kosten van wegverkeer in Vlaanderen, Studie uitgevoerd in opdracht van de Vlaamse Milieumaatschappij, MIRA,MIRA/2004/04, Transport & Mobility Leuven.