

ENERGY POLICY MAKING WITH EXTERNALITIES

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Abstract:

Costing of externalities of energy is an essential component in assessing the “right price” of energy. This paper describes a modeling methodology of externalities of energy and illustrates some estimations obtained for certain countries. Some considerations for energy policy making with externalities are also described in this paper.

Introduction

Sustainable development is an issue of prime importance, both now and in the future. Since the environment damage due to energy related activities is unavoidable, it constitutes a significant challenge to sustainable development. Choosing one energy option over another may be influenced by many technical aspects as well as the aspects of society and the environment. As such, it has been argued that the environment damage and subsequent health impacts related to energy should be accounted for, to obtain the highest net benefit for the society. In other words, to get the “right price” of energy, externalities of energy, which are typically not taken into account in establishing the market price, are to be considered in the pricing mechanism [1].

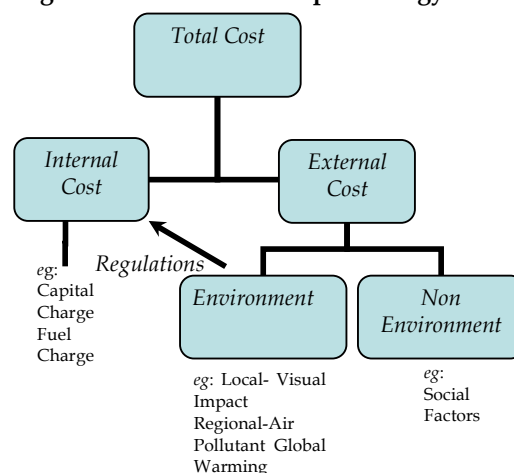
Furthermore, getting the right price is a prerequisite for market mechanisms to work effectively towards sustainable development in the energy sector. Traditionally, only the internal cost of energy is considered when pricing energy. However, in order to obtain the maximum net benefit to the society, the total cost of energy has to be calculated with the internal costs of generation and the external costs and benefits [2]. The internal cost is associated with fuel and maintenance costs, whereas the external costs are associated with the cost of the negative impact on the environment of their production. Approaches are developed in economic theories to assess and internalize external costs that can be easily applied to the energy sector as well.

In the recent past, there has been much progress in the analysis of environment damage and consequent public health risks related to energy systems. Thus, several major projects were conducted to evaluate the external cost of energy in countries such as USA and Europe [3]. Unfortunately, developing countries such as Sri Lanka have paid only very little or no attention to considering the externalities when selecting energy options or in energy pricing. Thus there is a lack of data on the cost of externalities of energy in these countries.

Owing to the significant changes in the global weather pattern and the environmental disasters in recent past, there is a growing concern on environmental impacts and thus it is opportune to investigate the externalities of energy development and use, even in Sri Lanka. This will enable the selection of the most suitable energy options by comparing their “right price”, which would maximize the net social benefit.

However, the main issue in estimating the total cost of energy is that there is no clear distinction between internal costs and external costs [3]. Environmental cost may be moved to become part of the internal costs by imposing environmental and health regulations. As an example, regulations for emission levels of a pollutant compels industry to install pollution control equipment, which may reflect as an internal cost in pricing, as shown in Figure 1.

Figure 1: Cost Relationship of Energy Costing



The following section of the paper illustrates a general guideline, on how to estimate externalities of energy.

Estimation of Externalities of Energy

Externalities are defined as un-priced costs or benefits directly imposed upon one agent by the actions of another agent. Externalities cause market variations in the sense that there exists a difference between the private and the social (private plus external) costs and as a result, there will be non-optimality from society’s point of view.

The most difficult issue from the practical point of view is how to cost the externalities of energy, because the marginal damage costs are not known. Because of this practical problem, several institutions worldwide conducted a series of studies to develop a methodology for measuring and estimating the cost of externalities of energy. Some of the studies [4] suggested using the economic cost of mitigating the emission of pollutants from a plant as the external cost of energy (see Table 1).

Table 1: Pollutants and Mitigating Costs for a Coal-fired Power Plant

Externality	Emission (lb/MWh) (1)	Control Cost (\$/lb) (2)	Mitigation Cost (\$ cents/kWh) (1)x(2)
SO _x	6.0	0.416	0.25
NO _x	6.0	0.92	0.55
CO ₂	1820.0	0.0006	0.10
Particles	0.3	0.167	0.005
Water Impacts	na	na	0.10
Land Use	na	na	0.40
Total			1.405

Source: F. Kreith, “Integrated Resource Planning” *Journal of Energy Resource Technology*, June 1993, Vol. 115, pp 80-85.

The main drawback of this approach is that, it does not consider the links of damages with the cost and consequently, mitigation cost is not the true external cost. Due to the increasing attention to the environment changes, several studies have been conducted in the late 1980s and in early 1990s, which have estimated some of the true cost of externalities associated with electricity production and fuel cycle. Most of these energy externality studies assess the

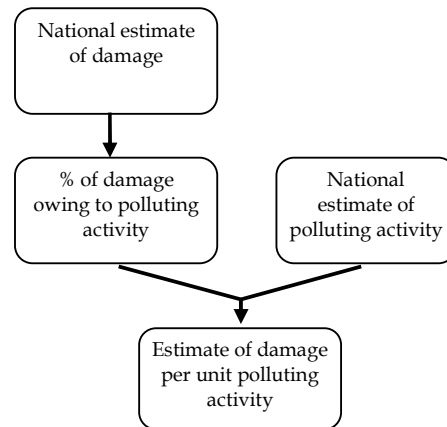
negative externalities (external costs), for different energy options.

Two prominent methodological approaches called “Top down approach” and “Bottom up approach” are identified to estimate the external cost of energy. In the “Top Down” approach, externalities of fossil fuel based power plant are studied using the following key steps [3];

- Develop an inventory of emissions (CO₂, particulate matter, NO_x, SO_x, and volatile organic compounds);
- Weighting these emissions by relative toxicity factors;
- Estimation of the contribution by these emissions to the total damage;
- Estimation of damage caused by such pollutants using available literature on estimates of environment damage.
- Combination of the numbers to obtain the cost of damage per kWh of electricity production.

This can be graphically illustrated as shown in Figure 2.

Figure 2: Illustration of Top Down Approach for Estimation of Externalities

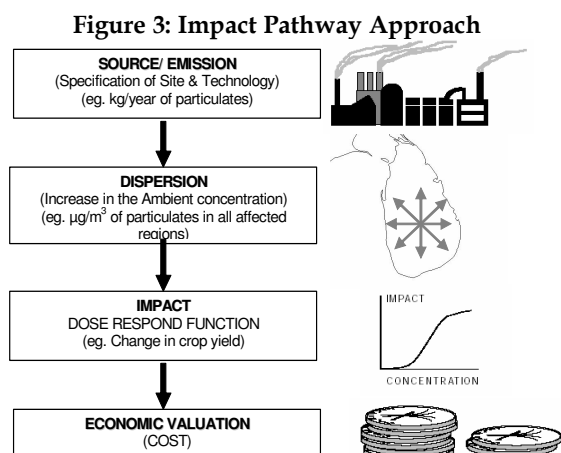


The “Top down” approach uses highly aggregated data and gives an average damage cost. This methodology needs relatively low data. The major problem with this approach is that it uses the relative toxicity factors which are derived from government regulations for minimum permissible concentrations at a place of work, and thus it does not reflect the exact damage to weight the emissions. This approach has not allowed any consideration of variation in impact due to technology, location (site specificity) or time. Therefore, this approach is

not considered as the best approach for calculating marginal damage cost due to activities associated with energy sector.

In contrast, the “Bottom Up” methodology uses technology-specific emission data for individual locations to calculate marginal damage cost. This method is also known as the “**Damage function**” or “**Impact Pathway**” approach [3]. This approach considers the detailed information on the location of receptors and the source of pollutant emitter, to calculate the physical impact of the emission. The value of these physical impacts is calculated using economic techniques. This valuation is based on individual preference, which is expressed through “**Willingness To Pay (WTP)**” and “**Willingness To Accept (WTA)**”.

Impact Pathway approach is also used in the recent study named “ExternE” project, which is jointly funded by European Commission and United States [3]. The main objective of this project is to develop an approach for the evaluation of external cost of energy production, covering a wide range of different fuel cycles. In the impact pathway approach, the assessment of externalities of energy is based on the sequence of events linking from “burden” to “impact”, and subsequent valuation. The principal steps of the Impact Pathway approach can be represented as follows (See Figure 3).



Characterization of the relevant technologies and the environmental burdens they impose (eg. kg/s of particulates emitted by the plant);

Calculation of increased pollutant concentration in all affected regions (eg. $\mu\text{g}/\text{m}^3$ of particulates,

using models of atmospheric dispersion and chemistry);

Calculation of physical impacts (eg. number of cases of asthma due to these particulates, using a dose-response function);

In some cases a fourth step may be called for: the economic valuation of these impacts (eg. multiplication by the cost of a case of asthma).

The first step of the impact pathway approach is to identify the source of emission and characteristics of the relevant technology and the environmental burdens imposed by that source (for example, the number of tons of particulates per GWh_e emitted by a power plant) by considering the factors such as technology used, location of power generation plant, type of fuel used, and the source, and the composition of the fuel used. Each of these factors is more important in determining the magnitude of impact and hence the associated externalities.

Then the calculation of increased pollutant concentrations in all affected regions due to power generation is done (for example increase of particulates in $\mu\text{g}/\text{m}^3$ per GWh_e in all regions affected by the power plant). Pollutants can be emitted to air, water or soil. The majority of pollutants are first emitted into the air, even if they later pass into water or the soil. Therefore, dispersion is analyzed as atmospheric dispersion, soil dispersion and transport by surface water.

Then the impact assessment is done to define the response as the incremental effect due to the dose. Dose-response functions are determined from epidemiological studies or from laboratory studies. Since the latter are mostly limited to animals, extrapolation to humans introduces large uncertainties.

The final step of environment costing is the economic valuation of the damage or in other words, estimate the monetary value of environment damage. This is done by estimating the WTP for environment improvement or WTA the environment damage. For example, for an illness one should count not only the treatment cost but also pain and suffering, as expressed by the willingness-to-pay to avoid the illness. Most pollution damage involves non-market goods such as

health or visibility, and therefore, their valuation involves indirect valuation methods that are difficult and costly to apply, such as contingent valuation, hedonic price method, and travel cost method. The most difficult and controversial good is loss of human life or human health. The amount for the health impact due to environment damage is determined by the Value of Statistical Life (VOSL), which is defined as;

$$VOSL = \frac{WTP \text{ for change in risk of death}}{\text{Amount of change in risk}}$$

Generally VOSL is determined by the following three different methods based on individual preferences:

Wage-risk studies: how much extra compensation do workers demand in jobs with high risk?;

Consumer market studies eg. how much are consumers willing to pay extra for safety measures such as air bags in cars?;

Contingent valuation: asking people directly how much they would be willing to pay if given the opportunity.

The impact pathway approach can be represented as an equation for the incremental damage D of a particular type (eg. asthma) due to an incremental quantity Q of a pollutant emitted by a source;

$$D = \sum_i f_{dr,i} [f_{dis \rightarrow i}(Q)]$$

where:

$f_{dis \rightarrow i}(Q)$ = C = increase in pollutant concentration for receptor i, and

$f_{dr,i}(C)$ = dose-response function for receptor i;

Dose-response function relates the quantity C of a pollutant that affects a receptor (eg. population) to the physical impact D on this receptor (eg. incremental number of deaths). For impact assessment, it is appropriate to define the response as the incremental (marginal) effect due to the dose. Thus, the dose-response function starts at the origin, and in most cases, it increases monotonically with dose C. At very high doses, the function may level off in S-shaped fashion, implying saturation.

Therefore we can define any dose-response function receptor i as;

$$D = \sum_i f_{dr,i} [C]$$

where:

D = incremental damage D of a particular type
C = increase in pollutant concentration for receptor i

Also we could write the increase in pollutant concentration for receptor i as;

$$C = f_{dis \rightarrow i}(Q)$$

where: Q = emission rate of particular pollutant

The ExternE project estimated costs for the externalities of energy in different countries and different technologies, and some of the results are shown in Table 2.

Table 2: Damage Estimation

Country	External Cost for Electricity Production in the EU Countries (ECU cent/kWh)						
	Coal	Oil	Gas	Nuclear	Biomass	Hydro	Wind
Austria			3		3	0.1	
Belgium	15		2	0.5			
Denmark	7	8	3		1		
Estonia	8		2		5		0.1
Finland	4	5			1		
France	10	11	4	0.3	1	1	
Germany	8	5	1		0.8	1	0.25
Ireland	8						
Italy		6	3			0.3	
Netherlands	4		2	0.7	0.5		
Norway			2		0.2	0.2	0.25
Portugal	7		2		2		
Sweden	4				0.3	0.03	
UK	7	5	2	0.25	1	0.07	0.15

Source: European Commission "External Cost", Journal of Research Results on Socio Environmental Damage Due to Electricity & Transport, 2003, pp 13.

Estimation of External Cost of Energy in Sri Lanka

There is no comprehensive study done in Sri Lanka to estimate the cost of damage of environment and welfare related to the pollutant associated with the energy sector. Furthermore, cost of externalities in the developing countries like Sri Lanka can be lower than that of developed countries, because it is very unlikely to have the same WTP and

WTA values in both developed and developing countries.

Thus, it is recommended that the cost of externalities of ExternE project can be used in other countries with suitable adjustment [3]. The World Bank has recommended to use per capita GNP ratio of two countries as the best way of estimating externalities of energy until we get a better idea of "GDP Elasticity" of WTP or WTA [5,6]. The estimated damage costs calculated on this basis are shown in Table 3, which have to be added to the apparent cost of production from each generating technology.

Table 3: Calculated External Costs of Energy for Sri Lanka

Generating Technology	External Cost of Energy (LKR/kWh)
Coal	0.74
Oil	0.40
Gas	0.22
Nuclear	0.02
Biomass	0.19
Hydro	0.02
Wind	0.01

External costs and Policy Making

Even though there are many limitations and uncertainties underlying the analysis of externalities and the valuation mechanism, the concept has a wide range of possible applications. It can provide valuable support to decision makers with regard to technology evaluation, comparison of future energy supply options, and cost-benefit analysis of policy measures. Furthermore, cost of externalities of energy is also a useful tool for technology designers, providing indicators of technology-specific sustainability and pointing to priority areas for the reduction of environmental impacts.

Furthermore, analysis of externalities of energy can provide a useful set of indicators on the sustainability of different energy technologies, which could help national energy policy making by:

- Providing reasonable indications for the "right price" of energy when considered in the pricing mechanism.

- Providing indicators of the sustainability of different energy alternatives.
- Pointing to opportunities to improve the sustainability of full fuel cycle operations.
- Helping to assess the impacts of different economic instruments such as carbon taxes or a carbon cap, and a trading system.

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