COMPARING DIFFERENT ENERGY RISKS: METHODOLOGY AND ISSUES

DECIDING THE WAY

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Comparative risk assessment of energy systems is based on two basic concepts. One is to describe indicators of health, environmental and other impacts from different sources of risk either quantitatively or qualitatively. The other is to compare these impacts with some criteria for making reports that energy decision-makers can use effectively.

This article briefly reviews major factors involved in the process of comparative risk assessment of energy systems for the production of electricity. Particular attention is given to the major issues that must be addressed in the decision-making process.

Study Approaches and Target Users. Many environmental impact assessments use qualitative approaches. They try to describe possible impacts in detail. Quantitative approaches, by contrast, may provide more transparent comparisons, but many issues are not quantifiable. They thus try to describe impacts to the extent possible.

The development of quantitative approaches has increased in the last several years, and they should give more transparency to, and facilitate, comparative assessments of energy systems. In this connection, they are more useful for assessing health and environmental impacts.

It should be kept in mind that the targeted users of comparative assessments are experts who will report to decision-makers. One type of decision-making process is energy policy-making. Energy policy-makers compare the impacts of alternative options when they make national policy and/or a company's policy on electricity supply and demand side management. In this case, the subject of policy-making might be the addition of electricity generation capacity to an existing national grid, systematic operation of a utility company's resources, or a change of state-level energy policy. The energy policy-makers can be officials in government and/or at electric utilities.

Another type of decision-making process is development of standards and/or criteria by regulatory bodies. Regulators can benefit from quantitative estimates of the impacts of alternative regulations when setting standards/criteria for permissible release of pollutants that might cause environmental and health impacts.

Methodology. Many studies of comparative risk assessment follow a methodology incorporating several steps. First, the path of events beginning with various activities in the energy fuel chain is tracked. Second, the emissions and changes in the ambient concentrations of the pollutants are assessed. Finally, the incremental impacts that result from these concentrations are evaluated.

Many studies also estimate the costs of these impacts. This approach is called the "Impact Pathway Approach" or the "Damage Function Approach". Because of the step-by-step analysis of each of the above series of assessments, this methodology gives transparency to the assessment process.

In defining an impact pathway, analysts have to distinguish between various terms — emissions, concentrations, impacts, damages, and the degree of "externality". *(See box, next page.)*

Emissions are the discharges from a power plant or from some other source in the fuel chain. Interpreted broadly, emissions include any residual effect such as noise (e.g., from wind turbines), the existence of a power plant where there was none before, or change in erosion (as a result of change in land use). With many pollutants, their emissions undergo chemical reactions or are dispersed from the source of the emission to neighbouring and far away

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DISTINGUISHING THE TERMS

The following examples illustrate distinctions between discharges, concentrations, impacts, damages, and externalities.

Emission or Discharge	Change in Concentration	Impact	Damage	Externality
CO_2	Increased concentration of CO_2 in the atmosphere.	Estimates of impacts are imprecise but thought to include changes in coastal ecosystems and in the built environment; changes in agriculture production; and possible starvation due to increased frequency of floods and droughts.	Economic value of the impacts.	In most countries, none of the damages are internalized; thus, all of the damages are "externalities".
SO_2	Formation, dispersion and change in concentration of sulphates, for example.	Increased risk of morbidity and mortality from respiratory problems due to inhalation of sulphates.	Economic value of the expected increase in morbidity and mortality. This value includes decreased, or lost, quality of life — not just medical costs and lost wages or productivity.	In regions without internalization of these damages, the externality equals the damage. In the United States, with trading of SO_2 emission permits, an indeterminate portion of the damages is internalized.
Radionuclides in the event of a nuclear power plant accident	Changes in concentrations of these radionuclides could extend for thousands of kilometers.	Increased risk of mortality and morbidity from certain cancers.	Economic value of the expected increase in cancers.	A portion of damages may be internalized, for example, in the United States through the Price-Anderson Act (insurance).
Noise from wind turbines	Change in noise levels at locations near the wind farm.	Undesirable effects on auditory senses.	Individuals express a willingness to pay to avoid noise, for example through real estate prices of land near the site.	All of these economic damages are externalities because there is not any market mechanism that internalizes them.
Reduced flow of a waterfall caused by hydro dam	Reduced flow of a waterfall caused by hydro dam (same as the "discharge").	Reduced visual aesthetics of the waterfall.	Economic value of the reduced aesthetics, as estimated for example in a contingent valuation study of individuals' willingness to pay.	None of the damage is internalized; thus all of the damages are externalities.

places. This dispersion changes the concentrations of pollutants relative to their levels without the activity of electricity generation. Populations, ecosystems, and infrastructure (such as buildings and roads) that become exposed to these changes in pollutants may be at greater risk of certain damaging impacts.

These impacts can, in many cases, be expressed in economic terms. One is "damage", and another is "externality". A damage is the full economic cost associated with a physical impact.

In some cases, the damages are not reflected in the market for electric power, or for the fuel. In such cases, they are considered as external costs or "externalities". Therefore, a portion of damage is the externality. The size of that portion depends on the extent to which market, insurance, and regulatory conditions explicitly account for the damages.

For example, the damages from SO_2 emissions in the Impact Pathway Approach include the economic values of the expected increase in morbidity and mortality. In cases where SO_2 emission permits can be traded, some portion of the damages is internalized, so the portion which is not internalized is the externality. However, in regions without ways of internalizing the damages, the externality equals the damage.

Other types of methodological approaches also are frequently used. For example, life-cycle analysis, life-cycle costing, and ecological risk analysis are other common approaches that also provide transparency in the assessment process. In these approaches, the focus and emphasis are different.

Also possible is to establish simplified methods that are useful for more general "screening" analyses, where detail is less important, and in situations where data or resources are very limited.

Indicators. Various indicators of health and environmental impacts can be used for the comparisons. In general, there might well be several pathways and end points that result from any emissions. These end points are indicators of impacts. In this connection, the indicators selected may depend on the choice of methodologies. As many impact indicators are selected, the process of comparison becomes complex. Therefore, a preferred approach is to choose priority impacts on which to focus comparisons.

Primary indicators of the impacts are estimates of the specific effects themselves, such as increased mortality rate, damage to trees, and increased rates of respiratory illness. Other indicators are often informative surrogates for these effects, particularly when they are difficult to estimate directly. The magnitude of pollutant emissions (and of other types of burdens) is one type of indirect indicator (e.g., tons of sulphur dioxide emitted). However, it must be recognized that indirect indicators are shown to be a good surrogate only in particular situations and cannot be used generally.

Among energy analysts, there is discussion regarding aggregated health indicators. While there is no consensus on which to use, "years of life lost" is becoming a commonly used indicator for mortality impacts, and "lost working person-days" for morbidity impacts.

Some analysts support more aggregated indicators, such as an integrated health index. Other analysts oppose this approach because detailed information would be lost through the aggregation process.

There is also discussion of the validity of an indicator derived by monetary valuation. One viewpoint is that only things that can be bought or sold have an economic value. Another is that monetary valuation is akin to the use of weighting factors (i.e. making trade-offs). Regardless, monetary valuation is appropriate when the decision process for which the study is being done requires it (e.g., for cost internalization) and when valid monetary values can be identified as the impact indicators.

One problem with monetary valuation is that it is difficult to place a monetary value on everything. An example is the bio-diversity issue, such as disturbing the habitat of a rare bird. Another example is that of using currency values for the impacts in different countries with different economic situations and social values.

Issues. When analysts undertake a comparative risk assessment, they have to recognize and sort out several issues. *(See box, page 13.)* These include setting temporal and spatial boundaries for the assessment, assessing future impacts, inclusion of global warming in the comparison, treatment of uncertainties, and ethical issues.

Boundaries need to be established consistent with the objectives of the assessment. There are several views on this issue. For example, those stages of the fuel chain not located within the assessing country's boundaries are not included in the scope of the assessment in many cases. However, when emissions from a foreign country can induce global impacts (e.g., CO_2), the impacts should generally be included. Emissions within national boundaries that lead to impacts in other countries should generally be considered as well. The difficulties in making such assessments are related to determining the dispersion of pollutants, exposures from hazardous materials, background levels, dose-effect relationships in other countries, and the values of impacts in different countries when monetary valuation is performed.

It is important to compare long-term health effects of both non-radioactive and radioactive emissions from nuclear and fossil fuel chains. However, long-term health impacts of toxic emissions and wastes from fossil fuel chains have not yet been assessed in a rigorous way.

Another issue for consideration is the discounting of future health impacts. Discount rates are commonly used to adjust future damages and benefits back to their present value, and then to express these on a "levelized" basis. Some analysts use discount rates that range from 0% to 10% to show the sensitivity of the results on the rate that is chosen.

There are many discussions on the ways of considering global warming issues in comparative risk assessment. The state-of-the-art can justify estimates of the emissions of greenhouse gases in different fuel chains. But it is significantly more problematic to derive quantitative estimates of the

SUMMARY OF MAJOR ISSUES IN COMPARATIVE ASSESSMENT OF ENERGY SYSTEMS

Issues	**Suggestions for Study Approaches**
Target users	Targeted users are experts who will report to decision-makers.
Decision-making processes	Types include energy policy-making; and the setting of standards and/or criteria.
Subject of policy-making	A marginal addition of electricity generation capacity to an existing national grid; systematic operation of a utility's resources; or a change of energy policy.
Setting boundaries	Determining environmental dispersion; exposures from hazardous materials; background level; dose-effect relationships in other countries; and values of impacts in different countries.
Aggregated health indicators	No consensus reached. Possible aggregated indicators are "years of lost life" for mortality impacts, and "lost working person-days" for morbidity impacts. No consensus reached on environmental impact indicators, though many are in use.
Monetary valuation	No consensus reached. One view is that monetary valuation should only be used when there are financial costs. Another view is that it can be used whenever trade-offs can be made among choices.
Ethical issues in monetary valuation	It is difficult to place a monetary value on everything (e.g., the bio-diversity issue) and to use currency values for the impacts in different countries.
Long-term health effects	Long-term health impacts of toxic emissions and wastes from fossil fuel chains need to be assessed. Discount rates from 0% to 10% are used.
Global warming	Advice of international bodies such as the Intergovernmental Panel on Climate Change (IPCC) is preferred.
Methods to reflect uncertainties	Analyst's subjective assessment (e.g., low, medium, or high precision); Monte Carlo generation of cumulative probability functions for the estimates; and schemes that allow analysts to describe systematically the uncertainty in the data.

health and environmental impacts that are expected to result from global warming due to those emissions. The consensus of international bodies, particularly the Intergovernmental Panel on Climate Change (IPCC), provides reasonably defensible assessments of the impacts of climate change.

Many analysts have described how uncertainties have been analyzed and presented in studies. Still at issue, however, is whether this subject is being handled in an adequate manner.

Ethical issues also are important and diverse. They are particularly relevant when assessing the monetary value of environmental impacts compared to health impacts.

Some might argue that it is ethically easier to attach monetary values to environmental impacts than to health impacts. However, many ecologists would argue that it is equally problematic to attach monetary value to ecosystems. It is thus difficult to satisfactorily address ethical concerns when estimating the value of different types of impacts due to the various contexts and the wide range of possible impacts.

In sum, analysts have to grapple with a range of issues in their comparative risk assessments of electricity generation systems.

To assist them in the process, the IAEA has prepared a technical report – entitled *Health and Environmental Impacts of Electricity Generation Systems: Procedures for Comparative Assessment* — within the framework of its inter-agency activities in this field.

The IAEA report describes the approaches and issues addressed in this article in greater detail. ❑