LONG-TERM HEALTH & ENVIRONMENTAL IMPACTS OF ENERGY SYSTEMS

AN EYE TO THE FUTURE

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All electricity generation systems hold some health and environmental effects for people living today but also for generations yet to come. Our current knowledge shows that several impacts are likely to appear in the far future, and they should be considered in evaluations of energy options.

Yet impacts likely to affect future generations are difficult to assess because of the long timeframes involved, and consequently they have not always been addressed. They should be, however. Even with limited information, the potential burdens should be analyzed, particularly because future generations cannot participate in the decisions that may affect their lives. The impacts from long-lived radionuclides, global warming, severe nuclear accidents, waste disposal, land use, and resource depletion are currently considered important to assess for future generations.

To consider future impacts, it is appropriate to define several timescales. There is no sharp delimitation between today's generation making a decision and future generations, so a time separation of about 50 years is assumed. One of the most important long-term impacts, global warming, will likely extend over a period of centuries. Others, especially the impacts of long-lived radionuclides, can extend over thousands or millions of years. Since the uncertainty of quantitative assessments increases greatly the farther we look into the future, results should be reported separately for different time periods. A natural horizon for the near far future can be set by global warming. Even though the timescale is not sharply defined, a cut-off of 100 or 200 years is considered suitable.

Photo: A coal-fired plant in Germany. (Credit: Siemens)

WHAT ARE MAJOR FUTURE IMPACTS?

Globally dispersed radionuclides. Among radionuclides released from nuclear power generation, two are dispersed routinely on a global scale and have long enough half-lives to be important for the assessment of future impacts: iodine-129 and carbon-14. Iodine-129 has a half-life of about 16 million years and it is readily incorporated into the global cycle of stable iodine. Carbon-14 has a half-life of 5710 years and will mix into the global carbon cycle.

The impacts to far future generations are mainly due to possible increased cases of fatal cancers and genetic effects resulting from increased low-level exposure to radiation. While the individual probability of exposure and detrimental effects are exceedingly low, the collective probability of large numbers of people exposed over a large number of generations (albeit

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ESTIMATED DAMAGES ARISING FROM LONG-TERM CLIMATE CHANGE

Type of Damage	Indicator of Damage	EU	USA	Ex-USSR	China	Non-OECD	OECD	World
Agriculture	Welfare loss (% GNP)	0.21	0.16	0.24	2.10	0.28	0.17	0.23
Forestry	Forest area lost (km^2)	52	282	908	121	334	901	1235
Fishery	Reduced catch (1000 t)	558	452	814	464	4326	2503	6829
Energy	Rise in electricity demand (TWh)	54.2	92.0	54.6	17.1	142.7	211.2	353.9
Water	Reduced water availability (km^3)	15.3	32.7	24.7	32.2	168.5	62.2	230.7
Coastal protection	Annual capital cost (million US $/yr)	133	176	51	24	514	493	1007
Dryland loss	Area lost (1000 km^2)	1.6	10.7	23.9	0	99.5	40.4	139.9
Wetland loss	Area lost (1000 km^2)	9.9	11.1	9.8	11.9	219.1	33.9	253.0
Ecosystem loss	Number of protected habitats assuming 2% loss	16	8	N/A	4	53	53	106
Health/mortality	Number of deaths (1,000)	8.8	6.6	7.7	29.4	114.8	22.9	137.7
Air pollution								
Tropical O_3	(1000 t NO_x)	566	1073	1584	227	2602	1,943	4545
SO_2	(1000 t sulphur)	285	422	1100	258	1864	873	2737
Migration	Additional immigrants (thousands)	229	100	153	583	2279	455	2734
Hurricanes								
Casualties	Number of deaths	0	72	44	779	7687	313	8000
Damages	millions of US $	0	115	1	13	124	506	630

Note: Damages estimated due to a doubling of carbon dioxide emissions into the far future (2.5° C warming).

Source: S. Fankhauser, "Valuing Climate Change", the Economics of the Greenhouse, Earthscan, London (1995). Derived from data of the Intergovernmental Pannel on Climate Change (IPCC).

to minuscule individual doses) amounts to a significant absolute total number. It is a matter of intense debate within the scientific radiation protection community whether such calculations are warranted at all, as the real risk may be zero.

Genetic impacts are considerably smaller than the risk of possible induced cancers, and more detailed explanations are available in other studies, such as the European Commission's ExternE project in 1995.

Global warming. Global warming is currently viewed as potentially one of the most important environmental impacts arising from the greenhouse gas CO_2 produced by the combustion of fossil fuels. An additional energy-related greenhouse gas, methane (CH_4), is released during coal mining or from leaks of natural gas systems; methane can also be released due to flooding and anaerobic fermentation after construction of hydroelectric projects. Even if the released quantities of methane are small (leakage rates are below 1% in modern natural gas systems), their impact can be significant because methane's global warming potential is 20 to 50 times larger than that of CO_2.

Although our ability to quantify human influence on global climate is currently limited due to the natural variability and uncertainty in available data, the Inter-governmental Panel on Climate Change reports that "the balance of evidence suggests that there is a discernible human influence on global climate". There is substantial agrement that a relative increase of atmospheric concentrations of greenhouse gases could potentially have diverse and large impacts on the climate. These impacts would be on the same human and environmental receptors affected by other forms of pollution. The impacts of global warming are quite uncertain and will occur in the longer term; they are therefore more difficult to quantify.

The damages arising from climate change over the longer term can be presented in physical terms using a set of damage indicators. *(See table.)*

Severe accidents. A severe accident will release additional contamination into the environment. Potential impacts on human health can be considered into the far future (generally out to 10,000 years). The additional global exposures to future generations from catastrophic accidental releases are generally small compared with those from routine operations. This is partly due to the more localized distribution of any long-lived radionuclides and the low expected frequency of such accidents. Accidents of non-nuclear energy systems are not expected to have significant far future impacts. Effects of oil spills, for example, tend to disappear after several decades.

Wastes. Wastes from energy systems contain materials with a wide range of environmental half-lives. In considering far future impacts, analysts are concerned with long-lived radionuclides, long-lived materials in non-nuclear waste (persistent organics), and materials that remain forever (toxic metals).

The far future impacts of wastes generated today should be considered in light of today's waste management options. The potential impacts and costs hinge on the methods used to dispose of this waste. Two key issues that will have significant influence on the level of potential far future impacts from waste disposal are the choice of repository site and technologies (e.g. landfill, engineered near surface facility or geological repositories); and the management of repositories (monitored or non-monitored, retrievable or non-retrievable).

The future impacts will depend on how the repository is managed today and tomorrow, so a waste management scenario must be assumed for any assessment. In most past studies on comparative risk assessments, the non-retrievable (or permanent disposal) option has been chosen for both hazardous and radioactive waste.

Using a non-retrievable disposal approach results in a potential for impacts in the far future from many types of waste, not just nuclear waste. A variety of calculations has shown that future damages resulting from releases of high-level radioactive waste repositories would not be significant relative to the type of risks people are willing to live with every day. But the very possibility of such releases has evoked intense fears on the part of the public and remains one of the key arguments for the opposition to nuclear power. The potential future impacts of non-radioactive toxic wastes have not been studied in as much detail, although they can be long-lived and are often disposed of at the ground surface.

In view of the potential for far future impacts, an alternative that has been considered for different types of disposal is retrievable storage, thereby giving future generations the option of improving current waste management methodologies. This recognizes the fact that future generations are likely to have better technologies to address the waste disposal problem (for example, transmutation of radioactive wastes could conceivably become practical).

Land use. The production and subsequent supply of electricity has, and will continue to require the use of land and, therefore, have an impact on amount of land available for other purposes. It can be argued that such impacts are likely to be reversible in the future. But some practical experience, such as the US Superfund activities to reclaim contaminated land, has shown that even with existing technology, the resources and political will to address such problems may be lacking. The impact on land is probably one of the most contentious and socially significant impacts to be considered in energy policy decision-making. There may be significant social costs in the far future.

Resource depletion. Current electricity generation methods mainly consume non-renewable resources — fossil fuels and uranium. Fossil fuels are likely to be depleted faster than uranium. The data suggest that presently identified oil and gas resources will become scarce sometime within the next century. Coal reserves are estimated to be depleted within several centuries.

Taking this into account, a variety of changes can be speculated in the future sector of electricity generation:

- variations in the price of available resources and increasing exploitation of lower grade material, with the possibility of increased environmental impact;
- increased efficiency in the production and use of energy;
- increased exploitation of renewable energies;
- a shift to new technologies such as nuclear breeder reactors; and
- a shift from oil to substitutes as the raw material for the production of plastics.

Due to the short time horizon facing most decisionmakers, some far future impacts and costs of resource depletion may not be taken into account; however, this impact is more amenable to quantification than some of the others already discussed.

By applying macroeconomics, the progressive depletion of resources can be assessed, and models can simulate the effect of price variations. It must be kept in mind that the estimated consequences will be sensitive to the assumptions that are made on future technological progress and structural changes. Principles governing sustainable development suggest that a reasonable rate of resource depletion should be identified, ensuring both the present growth rate of economies and the long-term availability of a variety of resources.

WEIGHTING THE IMPACTS

The assessed impacts resulting from the use of different methods of electricity generation do not all have the same severity or importance to society. The key problem for comparative risk assessment is to find a common measure of impact or risk that will allow for direct comparisons between different types of impacts.

Most impacts are not directly comparable (e.g. increased number of cancers to the rise in sea level). Using a single metric to render them comparable is a great simplification; it can be instructive, yet misleading.

Mechanisms for incorporating the value (monetary valuation is a possible method) or weight of an impact (such as multi-criteria weighting) have been under consideration for decades among professional analysts. It is even more complicated when considering impacts to far future generations. Besides quantifying the level of risks that might occur in the far future, analysts need to think about whether future generations can accept the risks produced today. So far, there is no ideal solution or answer to these questions.

Monetary valuation methods begin with the estimated health, environmental, and societal impacts, to which economic values are assigned based on their level of importance to society. Non-market goods, such as health and human life, can be valued according to individual preferences (willingness-to-pay).

To express these future monetary values in equivalent present values, the standard economic tool of discounting has been used. For discounting within the present generation (near future impacts), it is generally accepted that the appropriate rate is the social discount rate, with a typical value in the range of 3% to 8%, as determined by observation of the market. To test the sensitivity of the choice of a social discount rate, two studies of the external costs of energy systems (those of the European Commission and Oak Ridge National Laboratories/Resources for the Future) have chosen 3% as a central value, and have shown the range of final results for 0% and 10%.

If discounting is to be used for assessment of far future impacts, the choice of the discount rate is particularly important. Discounting can reduce far future intergenerational costs to negligible levels, unless the rate is very close to zero. Another key question is whether there will be future technological advances (such as medical treatments) to significantly reduce risks considered important today. For these reasons, intergenerational discounting has been a controversial subject. The question of whether a cost discounted to negligible levels adequately reflects the weight perceived by society must be resolved before the calculation of results can be considered acceptable.

Another key consideration is the importance of whether a risk is voluntary or involuntary. Risks imposed on future generations may appear to be involuntary. However, if the risks are made obvious, they can be avoided or reduced by taking appropriate actions.

For example, risks from a well-designed nuclear waste disposal site can be held to negligible levels if future generations continue to monitor and maintain the integrity of the site, thus avoiding any dispersal of the waste into the environment.

Despite the difficulties in quantifying possible impacts and costs of decisions about energy production systems, comparative assessments are valuable tools. They are an important part of the policy-making process that should not be overlooked in efforts to serve the best interests of generations living today and tomorrow. ❑