

# HEALTH & ENVIRONMENTAL IMPACTS OF ELECTRICITY GENERATION TARGETING SAFETY

BY ANNICK CARNINO AND FRIEDRICH NIEHAUS

**W**hen assessing energy options, today's energy planners and decision-makers must consider complex and difficult questions, particularly for the generation of electricity. A range of factors are at play. They are related to the entire fuel chain of the energy source, including technical and economic performance and health and environmental impacts. While costs remain a key factor, they must be measured in comparative ways. This fact, together with the needs of many countries to define their energy and electricity programmes in a sustainable manner, has provided the basis for a growing interest in comparative assessment of different electricity generation options, especially from environmental and human health points of view.

Against this backdrop, the IAEA has been supporting various activities in this field. (See box.) Related objectives have been to provide reference levels and consistent approaches in assessments of nuclear, radiation, and waste safety; to make increasing use of quantitative tools; and to serve as a repository for comparative information, including methods of assessment and approaches to comparisons.

Progress has been achieved in both areas, though a few difficult issues remain, as

articles in this edition of the *IAEA Bulletin* report. Through its work with Member States and international partners, the IAEA is seeking to strengthen the factual base of information that energy planners and decision-makers can rely upon in making their energy choices.

For all types of technological development, the safety objective is to adequately protect individuals and society from any associated hazards. Yet in spite of all safety precautions, the risks associated with large-scale technologies, however small, cannot be reduced to zero. Though it might be possible to reduce risks below given safety targets, the marginal cost of risk reduction will generally increase exponentially, and eventually result in a misallocation, or even a waste, of limited financial and human resources that are needed for other purposes.

To address this situation, it is necessary to quantify the residual risks of technologies, especially those for electricity production. The aim is to objectively compare them with each other or with naturally occurring risks to obtain a benchmark for assessment. It is not surprising that all aspects cannot be quantified, and that large uncertainties exist in particular areas.

Within this framework, a particular focus of the IAEA,

given its international mandate, has been on issues related to nuclear, radiation, and waste safety. In 1992, the International Nuclear Safety Advisory Group (INSAG) — an expert body advising the IAEA Director General — issued *The Safety of Nuclear Power*, a report that included relative health risks in electricity generation in consideration of the total fuel chains. The report's base of quantitative information has added to the transparency and understanding of comparative risk assessments.

## REFERENCE LEVELS & APPROACHES

Among the uses of comparative information has been to set target values for the low probability risk of severe accidents in nuclear power plants. INSAG, in a 1988 report (*Basic Principles for Nuclear Power Plants*) formulated the technical safety objective. It reads as follows: "to prevent with high confidence accidents in nuclear plants; to ensure that, for all accidents taken into account in the design of the plant, even those of very low probability, radiological consequences, if any, would be

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*Ms. Carnino is Director of the IAEA Division of Nuclear Installation Safety and Mr. Niehaus is Head of the Division's Safety Assessment Section.*

*minor; and to ensure that the likelihood of severe accidents with serious radiological consequences is extremely small”.*

Within the nuclear industry, the objective is addressed by considering a range of accident conditions and by equipping nuclear plants with engineered safety features to prevent and control accidents. More problematical is the INSAG goal of ensuring “extremely small” radiological consequences in the event a severe accident does occur. A number of IAEA Member States have sought answers by making use of results from comparative risk assessments. (*See the article beginning on page 25.*) Some have done so for nuclear power plants only, while others have considered potentially hazardous industries in general.

## NUCLEAR PLANT SAFETY TARGETS

In 1992, the IAEA published probabilistic safety targets for nuclear power plants in its *Safety Series No. 106*. They were based on work being done in the Agency’s Member States. Though today’s approaches in various countries may differ in their underlying rational and mathematical formulations, they are generally close to the targets issued by INSAG in 1988: *“The target for existing nuclear power plants consistent with the technical safety objective is a likelihood of occurrence of severe core damage that is below  $10^{-4}$  events per plant operating year. Implementation of all safety principles at future plants should lead to the achievement of an improved goal of not more than about  $10^{-5}$  such events per plant operating year. Severe accident management and mitigation*

*measures should reduce by a factor of at least ten the probability of large off-site releases requiring short-term off-site response.”*

The use of such targets, and of probabilistic safety assessment (PSA) in general, was further detailed in a 1992 INSAG report entitled *Probabilistic Safety Assessment*. The 1988 INSAG report presently is being revised.

## INTERNATIONAL CONSENSUS

Reaching international agreement is sometimes a very cumbersome process. So far, a strong consensus has not been achieved on probabilistic safety targets for nuclear plants. The IAEA’s published safety documents reflect this situation. For example, the Agency’s 1993 publication *The Safety of Nuclear Installations* (published as Safety Fundamentals, the highest category of IAEA safety standards) does not contain probabilistic targets in the main report (which would indicate consensus among Member States) but includes them in an annex to the document under a generic heading.

Further studies in the framework of comparative risk assessment might contribute to achieving a stronger international consensus of probabilistic targets. However, more precise comparisons may not be of dominating importance for setting targets at this stage. There is no strict mathematical relationship between probabilistic targets and the results of comparative risk assessments. The establishment of risk (or safety) targets is a political/policy decision and comparative risk

assessment provides one source of information for selection of the targets.

Considering the uncertainties of PSA results, the question remains as to how to demonstrate compliance with targets if they are set. In addition, the interpretation that PSA results represent a *quantitative indicator of the technical robustness of a plant*, rather than the measure of “risk” — appears to be growing in the technical community. At the plant level, risk may be influenced by factors that are difficult to model or cannot be included in a PSA. For example, the plant’s management of safety, as well as its overall safety culture, are significant contributors to overall safety levels by providing additional barriers against the occurrence of an accident. However, these elements are only partially reflected in PSA results.

Debate within the nuclear community presently revolves around the design of future reactors. Some argue for reactors designed with safety features that would practically eliminate severe radiological consequences. Others argue for a more evolutionary approach, whereby reactors are modified to achieve ever decreasing probabilities for core damage and radiological releases. It seems that comparative risk assessment cannot contribute to finding the answers to this debate.

## INFORMATION EXCHANGE

Part of the IAEA’s work in this field continues to be the compilation of objective comparative information to aid

decision-makers. In 1991, the Senior Expert Symposium on Electricity and the Environment in Helsinki recommended the establishment of a comprehensive and internationally coordinated database on the health and environmental impacts of different energy sources. Such a database has been set up and it incorporates the results of all recently published studies. Information also has been compiled through a Coordinated Research Programme involving twelve participating countries.

The database is being maintained in cooperation with other international organizations. In the year 2000, the Agency is planning to hold a technical committee meeting to compile and review what has been learned from all the work done.

Clear from the data is that important progress has been made over the past decade to reduce health and environmental impacts of all energy systems for the production of electricity.

They include the notable strides in the field of nuclear plant safety, and advances concerning other electricity generation sources. Filters and scrubbers to remove polluting gases have been introduced at fossil-fueled electricity plants, the safety of coal mines has improved, risks have been reduced from energy-related transports, the efficiency of gas generation technologies has improved greatly, as has the efficiency of renewable energy technologies.

Consequently, the pending issues in comparative risk assessment of energy systems have been reduced to a few, albeit very important ones.

### INTERNATIONAL COOPERATION ON COMPARATIVE ASSESSMENT OF ENERGY SYSTEMS

Working with regional and international partners, the IAEA has long supported studies of energy options for the production of electricity. Activities include sponsoring international symposia and supporting technical and scientific studies. Today the IAEA, through a programme entitled Comparative Assessment of Energy Sources under its Department of Nuclear Energy, conducts a range of activities. Articles featured in this edition of the *IAEA Bulletin* focus on studies related to health and environmental impacts and risks of energy systems, an element of the Programme carried out by the IAEA Department of Nuclear Safety. For more information on the Comparative Assessment programme, visit the respective pages of the Department of Nuclear Energy and Department of Nuclear Safety on the IAEA's *WorldAtom* Internet site at <http://www.iaea.org>. Listed below are selected symposia related to this field that have been sponsored by the IAEA and other organizations over the past decades. Proceedings of the meetings have been published by the IAEA.

**JUNE 1981: INTERNATIONAL SYMPOSIUM ON HEALTH IMPACTS OF DIFFERENT SOURCES OF ENERGY, NASHVILLE, USA.** Organized by the World Health Organization (WHO), United Nations Environment Programme (UNEP), and the IAEA.

**APRIL 1984: INTERNATIONAL SYMPOSIUM ON THE RISKS AND BENEFITS OF ENERGY SYSTEMS, JUELICH, GERMANY.** Organized by the IAEA, UNEP, and WHO.

**MAY 1991: SENIOR EXPERT SYMPOSIUM ON ELECTRICITY AND THE ENVIRONMENT, HELSINKI, FINLAND.** Organized by the European Commission (EC), International Energy Agency, International Institute for Applied Systems Analysis (IIASA), Nuclear Energy Agency of the Organization for Economic Cooperation and Development (NEA/OECD), UNEP, World Bank, World Meteorological Organization (WMO), the former Council for Mutual Economic Assistance, and the IAEA.

**OCTOBER 1995: INTERNATIONAL SYMPOSIUM ON ELECTRICITY, HEALTH AND THE ENVIRONMENT: COMPARATIVE ASSESSMENT IN SUPPORT OF DECISION MAKING, VIENNA, AUSTRIA.** Organized by the EC, United Nations Economic and Social Council for Asia and the Pacific, Organization of Petroleum Exporting Countries, World Bank, United Nations Industrial Development Organization, IIASA, WMO, UNEP, and the IAEA.

They include the significance of the formation of small secondary particles from sulphur dioxide emissions; the impact of carbon dioxide on climate change; additional analysis of very long-term effects of low doses from chemical or radioactive substances; and the evaluation of events that have a low probability of occurring but would have high consequences if they do happen.

The resolution of these important and difficult issues may not be possible from the standpoint of achieving international consensus.

More likely, they will have to be independently evaluated and judged separately on a case-by-case basis in the governmental decision-making process of analyzing and defining sustainable energy choices.

Through its activities, the IAEA is working to strengthen key areas of nuclear, radiation, and waste safety. An important aspect is that work is pursued within the broader framework of comparative safety assessments of all major energy systems used for the generation of electricity, and involves a range of global partners. 