almost 40 years, that is, well beyond the mean turnover life of circulating lymphocytes, which was estimated at about three years.

Regarding late health effects, an increase in frequency has been established for some malignancies, for eye lens opacities, chromosomal aberrations, small head size and mental retardation (for *in utero* exposed), and retardation in early growth and development.

Two interesting findings were mentioned in regard to the monumental Hanford animal studies on plutonium and radium toxicology and the possibility of extrapolation to man. Burros, a type of medium-sized donkey, and Chinese hamsters have been found to be refractory to cancer induction by inhalation of plutonium. New studies will be initiated to investigate the causes, and to possibly take advantage of this naturally occurring resistance to cancer.

The second finding is that, as far as association of cigarette smoking and radon daughters is concerned, it still is unclear whether cigarette smokers are at greater risk than non-smokers to radiation-induced lung cancer at relatively high radiation doses and even more uncertain at low radiation doses.

Special consideration also was given to the assessment of plutonium and other actinides in the respiratory tract. The new realistic "chest phantom" stirred a lot of interest among participants.* Several requests were forwarded to IAEA by specialists from different countries to obtain information on its availability.

* The "chest phantom", developed by IAEA for use by Member States, is a device used in calibrating equipment for measuring plutonium deposition in the lungs.

Risk assessment: Energy & life expectancy

by Friedrich Niehaus

During the last century, technological development has been associated with an increase of about 35 years in average life expectancy, an increase mostly attributed to a decline in infant mortality – an important factor of improved health associated with industrial prosperity.

Although it is difficult to single out energy's contribution, it is safe to assume that at least 10%, or 3.5 years, of this increased life expectancy can be attributed directly to sufficient energy supplies, a key parameter in technological development.

To better assess energy's health and social impacts, IAEA recently organized a symposium in co-operation with the United Nations Environment Programme (UNEP) and the World Health Organization (WHO).*

Mr Niehaus is Project Leader of the Risk Assessment Section in the Agency's Division of Nuclear Safety.

* The symposium was officially entitled "Risks and Benefits of Energy Systems" and held in Jülich, Federal Republic of Germany, 9–13 April 1984.

About 180 participants representing 36 countries and 11 organizations attended. One clear emerging viewpoint was that decisions about energy systems must be based on an assessment of many different aspects regarding their risks and benefits.

Benefits outweigh risks

As shown in the accompanying chart, health costs to society of energy production are relatively small compared to the benefits. "Safer" energy sources, such as natural gas and nuclear power, typically cause about one death per gigawatt of electricity produced annually, most of which can be attributed to occupational risk.

Other energy systems range about one order of magnitude higher, with large uncertainties about public health effects from airborne emissions of burning oil or coal. If a country uses five kilowatts *per capita* (typical in European countries) – which translates into five gigawatts per million people per year – these data

show an average decrease in life expectancy of between 0.1 and 0.01 years.

Thus, health benefits from energy production outweigh health risks by a factor of 30 to 300.

Biggest risk: not enough energy

Among countries in the world, energy consumption *per capita* is unevenly distributed. In Canada, for example, *per capita* energy consumption is 100 times that of a developing country such as Bangladesh. Therefore, much more energy will be needed in the future, and the largest risk will be insufficient energy supply – two facts stressed at the symposium. More efficient energy utilization could secure a threefold increase in global economic output in the next 50 years, with global primary energy consumption alone roughly doubling.

However, a threefold increase in global economic output will not solve the dilemma of developing countries because of rapid population increases. The gap between gross domestic product (GDP) *per capita* in developing and developed countries is likely to increase drastically. To secure economic growth in developing countries, sufficient energy supply then is one crucial parameter.

This dilemma is aggravated by the fact that the energy intensity of developing economies is much higher than that of developed countries. It was projected that by the year 2030 developed regions would need about four kilowatt-hours per dollar of GDP, while developing regions would require twice that amount of energy. Electricity's share of total energy consumption will increase steeply in all regions.

Other aspects to consider

Risk comparisons of energy systems show a definite rank ordering per unit of energy produced, but risks are only one aspect in defining an appropriate energy mix.

In the long term, energy technologies could be developed that would lead to practically zero emissions on the producer side. However, in the short run, it is necessary to define risk management strategies that would make the most efficient use of available resources for environmental protection. Several papers presented case studies suggesting that cost-effectiveness analysis is an appropriate tool for defining risk management studies.

Some long-term impacts of energy systems are difficult to evaluate. It was shown that burning fossil fuels leads to an increase in atmospheric carbon dioxide concentration that is likely to raise average global temperature. In the short term, this could effect world food production and, in the long term, the earth's ice cover.

Need for better communication

There was general agreement that available techniques to analyse risks and benefits of energy systems are useful for application in developing countries.

However, it was recognized that great difficulties arise in translating results of scientific assessments into language understandable to decision-makers and the general public. Several papers presented survey results indicating that the public feels ill-informed and has a strong interest in obtaining more information about energy-related questions.

Participants clearly expressed the view that international organizations – in particular, IAEA, UNEP, and WHO – should closely co-ordinate their efforts to promote application of developed techniques, to generate and compile information on energy risks and benefits, and to translate and transfer results to those institutions that have to make the political decisions.

Health benefits and risks from energy production

Life expectancy changes from technology during past century

Technology (general)	plus 35 years
Energy's share	plus 3.5 years
"Safer" energy sources [1 death per gigawatt per year]	minus 0.01 years*
Other energy sources [10 deaths per gigawatt per year]	minus 0.1 years*

* Decreases assume annual energy consumption of 5 gigawatts per million people.

(Source: D.K. Myers et al.)