Studies of Risks from Different Energy Sources: Methodological Comments

by M. Bertin

This theme has been the subject of much research in recent years and several scientific meetings have been devoted to it. It is thus very relevant to the present day, and we now have a much clearer view of what results can be expected from such research.

REASONS FOR THIS RESEARCH

Four factors have been instrumental in prompting such studies. First, there is the development of the nuclear power industry, which is often considered to involve risks much greater than – and even out of all proportion to – those of other energy industries. The Hiroshima and Nagasaki explosions surely explain this view. The nuclear power industry has been in existence for 25 years without a single fatal radiation accident in industrial facilities. That is why the nuclear industry, believing itself to be wrongly accused, has prompted this work – a course of action which is naturally not without ambiguity.

Secondly, there are the scientific and medical advances which have now brought to light dangers unsuspected just a few decades ago. Examples of these are the roles that may be played by a growing number of physical and chemical agents in the development of cancers, the occurrence of deformities due to effects on the foetus during pregnancy, and the induction of genetic mutations.

Other examples are changes in ecosystems and the indirect effect on man of toxic substances which have passed through food chains. Nor are these the only examples that could be given. It is only logical then to try to determine whether these various effects have been properly taken into account thus far when taking stock of the possible risks from different energy sources.

Study of the possible effects on health of the nuclear power industry at these different levels is therefore essential. It is only right, too, that we should ask ourselves whether these factors were taken into account in the case of what are termed traditional energy sources.

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RESPECTIVE RISKS OF DIFFERENT ENERGY SOURCES

These sources developed very rapidly, and also only quite recently. World coal production stood at 20 million tonnes in 1800 and is now more than 2000 million tonnes. The use of oil is more recent: 800 000 tonnes in 1880 and 3000 million tonnes today. The exploitation of natural gas began at an even later stage.

It is also of vital importance to determine whether "new energy sources" – some of which have been dubbed "soft energy sources" – pose problems for the environment and public health. The same applies to new energy production techniques (gasification of coal, for example) and to our ways of using them (means of transport and so on).

Finally, there is a fourth, psycho-sociological, factor which has undoubtedly played a large role. The concern of public opinion for the environment in which we live is a comparatively recent phenomenon and everyone agrees that the evolution of society in recent decades has been accompanied by negative aspects (excessive urbanization, artificial needs created by the consumer society). Many people believe that this evolution and growth in energy consumption go hand in hand. This is a further reason for attempting to take stock of the situation in order to assess the advantages as well as the drawbacks which increased energy consumption entails for health.

TYPE OF RESEARCH

Research into the risks of different energy sources has, of course, been under way for some time. The new element is that of comparison.

The studies fall into three categories. Firstly, *study of a specific risk.* This applies, for example, to studies on silicosis in miners, or cases of electrocution and asphyxia due to combustion gases. The main aim originally was to make a medical assessment of the risks: clinical and biological description, prognosis, treatment, recording and treatment of complications and after-effects. Since then, epidemiological studies have been carried out on various risks and, as a result of long series of statistics, it is now possible to assess risk growth as a function of many factors. The examples given by Dr. Amoudru[1] with respect to industrial accidents and pneumoconiosis in coal mines, and by Dr. Pequignot[2] with respect to cases of asphyxia due to gas and of electrocution, may be mentioned.

A second type of research consists in *examining, for one specific risk, all the problems posed by a particular energy source.* An example of this is the irradiation resulting from nuclear power production at different stages of the fuel cycle.

In order to run a nuclear plant, facilities are required, "upstream" of the plant, for:

- the extraction of uranium ore,
- the refining of this ore;
- purification and conversion into uranium salt or uranium metal;
- possible enrichment;
- the fabrication of fuel elements,

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[1] See pages nn to nn of this Bulletin.

[2] See pages nn to nn, ibid.

and, "downstream" of the plant, for·

- reprocessing of spent fuel and storage.

Thus, when we are talking about irradiation due to nuclear power production, all these stages must be borne in mind.

Furthermore, this irradiation can affect:

- Staff employed at the various stages of the cycle, including miners in uranium mines and the personnel of nuclear plants and reprocessing facilities;
- The population as a whole, because of the possible spread of long-lived radionuclides; and
- The so-called "critical" sections of the population, such as people living in the immediate vicinity of nuclear facilities.

Lastly, irradiation may occur in a number of forms: it can be direct, through external exposure or contamination, or indirect through the environment where radioisotopes follow complex pathways.

The studies called for are both medical and technical; they must allow an assessment to be made, for each of the stages involved in the various production techniques (the different nuclear systems), of the radiation sources, the waste produced and the health effects which may result.

Table 1, which was published in the 1977 UNSCEAR report, indicates the annual doses received by individuals exposed, occupationally or otherwise, from all the facilities required for a plant with a capacity of 1 MW(e). All exposed individuals taken together thus receive a collective dose of between 5.2 and 8.2 man-rad.

Similar studies could be carried out for a number of chemical substances. The best example to use is asbestos. Asbestos has taken a heavy toll of miners in the mines of Canada and South Africa. It was doctors from the latter country who described pulmonary asbestosis, but it was British and American investigations of workers in shipyards which demonstrated the extent of the problem. Asbestos was used in shipyards for insulating and heat-proofing. Mr. Califano, formerly Secretary in the US Department of Health, talked of millions of people being exposed to the risk of asbestosis and cancer. However, asbestos has also been used in constructing houses and places of work – in other words on a very wide scale; a host of objects from toasters to brake-pads on cars also contain asbestos. The whole population is thus affected to a greater or lesser degree.

The difference between the nuclear power and asbestos industries is that, in the former, research was undertaken before the harmful effects were detected, while in the latter research was only carried out afterwards. In fact, it is only in the last few years that a record has been kept for asbestos: an inventory of health effects and an inventory of exposures, together with the setting of standards and the establishment of dose measurement techniques.

However, given the spectacular growth in the uses of asbestos during the last 35 years and the very long latency period for lung cancers and pleural mesothelioma, there can be no

Table 1. Evaluation of Annual Doses due to Nuclear Power Production

Step in fuel cycle	Type of radiation	Collective dose man-rad/MW(e)/yr
Extraction Processing Fabrication	Occupational	0.2–0.3
Reactor operation	Local – regional Occupational	0.2–0.4 1
Reprocessing	Local Global Occupational	0.1–0.6 1.1–3.3 1.2
Research	Occupational	1.4
TOTAL		5.2–8.2

doubt that in the twenty years to come a number of cancers will be detected in individuals who were exposed before these standards were set.

The third type of study is relatively recent and allows *effective comparisons to be made between different energy sources.* The goals of these studies are ambitious. They aim at covering:

(a) All risks

– Some risks are specific while others are not (industrial accidents, for example);
– There are occupational risks (occupational diseases) and those which affect the population;
– There are both diseases and accidents and, in this case, not only their seriousness but the probability of occurrence also must be taken into account;
– One must take into account not only particularly exposed individuals (workers or populations living in the vicinity of potentially dangerous facilities) but also the population as a whole as it may be affected by some long-term risks (long-lived radionuclides, increases in the concentration of carbon dioxide in the atmosphere);
– The many mechanisms through which living creatures may be affected must also be taken into account.

(b) All activities which are part of the establishment, smooth running and dismantling of the facilities required for an energy system.

In particular, all economic and industrial activities involved in creating the necessary industrial facilities must be included in the studies. An example will serve to show why this is the case. Virtually no risk is attached to the operation of the various plants which form a hydroelectric facility: the staff is small and the facility highly automated. However, its construction will have produced a number of industrial accidents (perhaps a few dozen deaths in the case of some large dams) and involved silicosis risks (when driving galleries) for the workers of public works companies; the manufacture of the equipment used (turbines, alternators, etc.), the production of tens of thousands of tons of concrete (quarries, factories, transport, etc.), of steel (iron mines, iron and steel works, mechanical industries, etc.) and of various metals (aluminium, copper, etc.) will have entailed other accidents.

Given present techniques, solar power requires more investment than nuclear to produce the same capacity.

FACTORS TO BE TAKEN INTO ACCOUNT

There is no point in comparing these *three types of research* as they are complementary and provide different information.

However, only the last type of analysis allows real comparisons to be made, but there are obvious difficulties: incomplete data with variable values, use of "models" and choice of theories which are difficult to verify, and the summing of very different "effects".

To reduce this complexity, many studies have been restricted to a comparison of the risks attached to the annual production of a certain amount of electricity or to electrical facilities of a given capacity. Problems of the transport, distribution and utilization of electricity are omitted. These studies enable, in particular, a classification to be drawn up among the different systems for producing electricity. Hamilton's publications have described this type of comparison at length.

Furthermore, as the complexity of the studies increases it becomes more difficult to draw general conclusions from them. If a large number of precise parameters are employed, they produce an increasingly accurate definition of a particular case; the results are all the more interesting, but more difficult to use for generalizations. For example, if a study concerns electricity production from coal the results will vary enormously depending on whether the coal is produced in the United States or France. In the former case, the coal in question is often produced in highly-automated and silicosis-free open-pit mines where output per person is several tens of tons. French mines, however, are very deep, extraction is difficult, output is much poorer and there is a risk of pneumoconiosis.

Each case is distinct, therefore, and these studies cannot be carried out unless a number of parameters with a fundamental effect on risks are defined.

Regulations

Risks depend, of course, on the quality and reliability of facilities; these in turn depend heavily on protection and safety regulations, which vary from country to country. For instance, the amount of radioactive waste which can be released to the atmosphere or water is defined by the regulations. Similarly, occupational exposures to toxic substances are governed by standards in some countries, they determine the "degree of acceptable risks". These standards however do not exist everywhere and – when they exist – differ from one country to another. Thus, even where production and technology are identical, the risks may vary depending on the regulations and how strictly they are enforced. In this area, voluntarist policies can significantly alter the risks involved.

Choice of sites for establishing production units

The consequences of an accident or incident which causes harm clearly vary greatly depending on the natural and human environment in which they take place. This is undoubtedly true of accidents. The collapse of the Malpasset dam near Fréjus in 1959 caused 421 deaths because of the size of the population living downstream and the situation of their houses.

It is also true for pollution: the effects of sulphur pollution depend on the type and amount of vegetation exposed (sulphur pollution in the Lacq region due to a gas purification plant). It also holds true for radioactive effluents.

There is another aspect to the question of siting: the harmful effects caused by energy production at a particular site are added to those already in existence these. The seriousness of the effects of atmospheric pollutants or the heating of river water, for instance, depends on the levels which already exist as there are "practical thresholds" for these different effects; they thus depend on the total quantity of pollutant material released or the total volume of hot water produced by the many industrial sources over a given stretch of river.

It is therefore impossible in such a case to assess the adverse effects of a particular installation as the real problem concerns the total amount of damage caused: it is the responsibility of the community to make a classification. This is what happens when sulphur pollution reaches a certain level in a built-up area and those industries considered largely responsible for pollution are forced to close down.

Site selection is not the only geographical problem

France is a country with limited energy resources and thus imports a large part of its requirements; more than half the coal it uses comes from foreign countries such as Poland, South Africa and the United States. The human risks attached to this component of coal production thus are not the concern of the French population.

But pollution can also pose problems at an international level. Atmospheric transfers over long distances are known both for some radioisotopes present in gaseous effluents and for some chemical atmospheric pollutants; the gradual acidification of the Scandinavian lakes and the gradual deterioration of the forests of those countries is attributed to sulphur pollution originating mainly in Britain, but also in all of central and western Europe.

RESPECTIVE RISKS OF DIFFERENT ENERGY SOURCES

The time factor must also be taken into account

Techniques, regulations, measurement methods and their accuracy develop very quickly. Rapid progress is also being made in medical and biological knowledge, and in safety and prevention. This helps to make the situation today very different from what it was thirty years ago. The health problems posed by the production and transport of electricity have changed.

In 1950, efforts were directed towards the construction of coal-fired thermal power plants equipped with units of 125 MW, although EDF (Electricité de France) was trying hard to develop hydroelectric installations. Today, the orientation is principally towards nuclear power plants. The precautions taken then to protect the environment were clearly far less comprehensive than those taken now. Coal-fired power plants today are fitted with dust removers which eliminate 98 per cent of the dust that would otherwise be released to the atmosphere. The sulphur content of the fuels used is limited and the concentrations present in the atmosphere are measured at regular intervals. Precautions taken to protect sites are thus much more extensive than they were thirty years ago.

It is probable, therefore, that this progress will continue, and accordingly it is difficult to extrapolate from the present situation to the situation which will prevail in ten years' time, for example, to say nothing of the period of fifteen or more years hence.

HEALTH

One of the main problems of these studies is the relative value of health data. The volume and value of available data bear no relation to the actual size of the risk: much more is known, for example, about occupational risks than about risks to users, but it is not certain that the latter are not in fact greater. It often happens that there are voluminous data on a particular risk which is well-known and fully under control. Finally, the amount of resources allocated to the problem depends less on its real seriousness than on the way in which it is felt and on who is responsible.

Attributing a non-specific health effect to a cause is sometimes extremely difficult. How does one attribute, for example, a part of chronic lung disease to a particular source of chemical or particulate atmospheric pollution?

Another difficulty is that health gauges or indicators are of limited value. The traditional indicators are mortality and morbidity expressed in terms of the incidence or prevalence of well-defined diseases as they appear in a classification such as that of the World Health Organization. They record very different data: they do not take into account the degree of seriousness, the basic risk, the length, the degree of disability and the repercussions of a disease, factors which mean that no two cases of the same disease are ever exactly alike.

Furthermore, big differences can arise depending on the persons who register these data: doctors providing medical care, whether in hospital or elsewhere, organizations responsible for drawing up health reports, administrative bodies responsible for allocating benefits, or the patients themselves. The attitude to a disease is extremely important: a chronic lung disease may be more disabling and intractable and have a bleaker prognosis than cancer, but in general the latter is felt to be more serious.

Finally, great importance is very often attributed to the economic consequences of the illness: lost working days and days of hospitalization, benefits and the cost of care, the degree of disability and the corresponding compensation, expression of a death in terms of years of work lost.

Paradoxes arise whereby a disability is seen as being more serious than a death because it costs more and where the importance of a death varies depending on whether it was an industrial accident or an accident to a user, the former also costing more. The economic consequences of equally serious accidents or diseases also differ, of course, depending on the medico-social protection of the victim.

More complex and elaborate indices have been proposed recently, but these deal more with the socio-economic impact of health problems and the work of the medical care system. It is unlikely that they will be used in the type of study envisaged here.

In conclusion, such indices are very useful at the medico-legal, economic and administrative levels but offer only a partial and often distorted reflection of the full complexity of health problems; it is in this sense that comparative studies can, if one loses sight of the relative value of these indices, give an inaccurate picture of reality.

CONCLUSION

The foregoing remarks allow us to define better what results can be expected from such studies. It is possible to assess the magnitude of the health risks attached to an energy system if precise parameters are defined for the case in question. It is not possible to obtain exact values, but upper and lower limits, or orders of magnitude, can be quoted. Comparisons can thus be made between the main energy systems either for total risk or, with more accuracy, for each of the main risks.

Many studies have now been published, making it possible to assess whether the choices which have been made with regard to energy policy take account of the risks and whether, where the risks are equal, the same safety conditions are required in all cases.

Similar investigations could be carried out for non-energy industries and for various economic activities.