Nuclear energy and the public: risk perception, attitudes and behaviour

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In almost all western industrial nations, the problems involved in public acceptance of the risks of nuclear facilities have resulted in an avalanche of psychological and social science literature devoted to the question of the development, origins and consequences of current reactions to modern technology. Parallel to these studies, attitudes toward nuclear energy have been measured, and opinion polls have been conducted to elicit the public's view on energy problems. All these efforts to explain public opposition have led to a confusing amount of data and theories which make it difficult to grasp the basic ideas. Nuclear scientists or technicians, who wish to obtain practical advice in order to deal with the nuclear debate, are often confused by the broad spectrum of theoretical approaches and possible interpretations. They are even more disturbed by the realization that the numerical results and the explanations given quite frequently vary, depending on the research institute involved and the attitude the researcher himself prefers. This unsatisfactory situation has reached such a point that representatives of pro- and anti-nuclear groups extract solely those statistical data which back up their own views.

If, indeed, the findings of the social sciences tend to reveal the prejudices and political goals of the researcher involved, it would be advisable to ignore this field of investigation and use common sense to come to terms with the public debate. Unfortunately, common sense is not of great assistance in a situation where the debating parties are unaware of their opponent's motives and incentives. Before finding an appropriate

reaction to public mistrust and fear, one has to ascertain the underlying causes of the hostility towards nuclear energy. One's own experience is no substitute for systematic analysis of attitudes and motives and sometimes leads to personal biases.

The research group at the Nuclear Research Centre, Jülich, has therefore tried to trace nuclear attitudes to their motivational roots. The objective was not to label nuclear opponents as psychologically deviant or emotionally overwrought. Neither did we intend to glorify pro-nuclear groups as rational thinking and responsible promoters of social progress. In fact, we did not evaluate opinions at all and did not comment on beliefs concerning energy systems. Our intention was merely to measure the structure of attitudes, to find common types of reasoning in this matter and to investigate the processes involved in making up one's mind about nuclear power. As a result we uncovered certain psychological or sociological factors which affect attitude formation.

Origin of attitudes: perception of technology and risk

Many investigations and surveys have been carried out to discover how people intuitively perceive technology and risk. The studies by Slovic, Fischhoff *et al.*[1-4], as well as recent work by Brown and Green[5] and Glennon,[6] clearly show that the expected value of loss (in the natural sciences usually referred to as risk) is not the main yardstick of intuitive risk estimation. Among other factors the circumstances of the risk are said to play a major role. We tested this hypothesis by using survey and experimental methods and measured the influence of the following variables:

perceived loss expectation;
the circumstances of the risk situations (so-called 'qualitative risk properties' such as freedom of choice, possibility of personal control etc.);
beliefs about the source of the risk;
special personality characteristics such as risk propensity.

Since expected values are important statistical tools in rating the hazardousness of an object, it was interesting to investigate how people estimate these values and what significance these have with regard to their judgement of the severity of risk. Surprisingly, most laymen had a fairly good estimative ability in calculating losses/year. Figure 1 shows the results of two surveys, one American, one German. A random sample of persons was asked to estimate the average losses/year from various sources of hazard: estimated values are plotted on the y axis and the actual statistical figures on the x axis. There is a general tendency, both in the

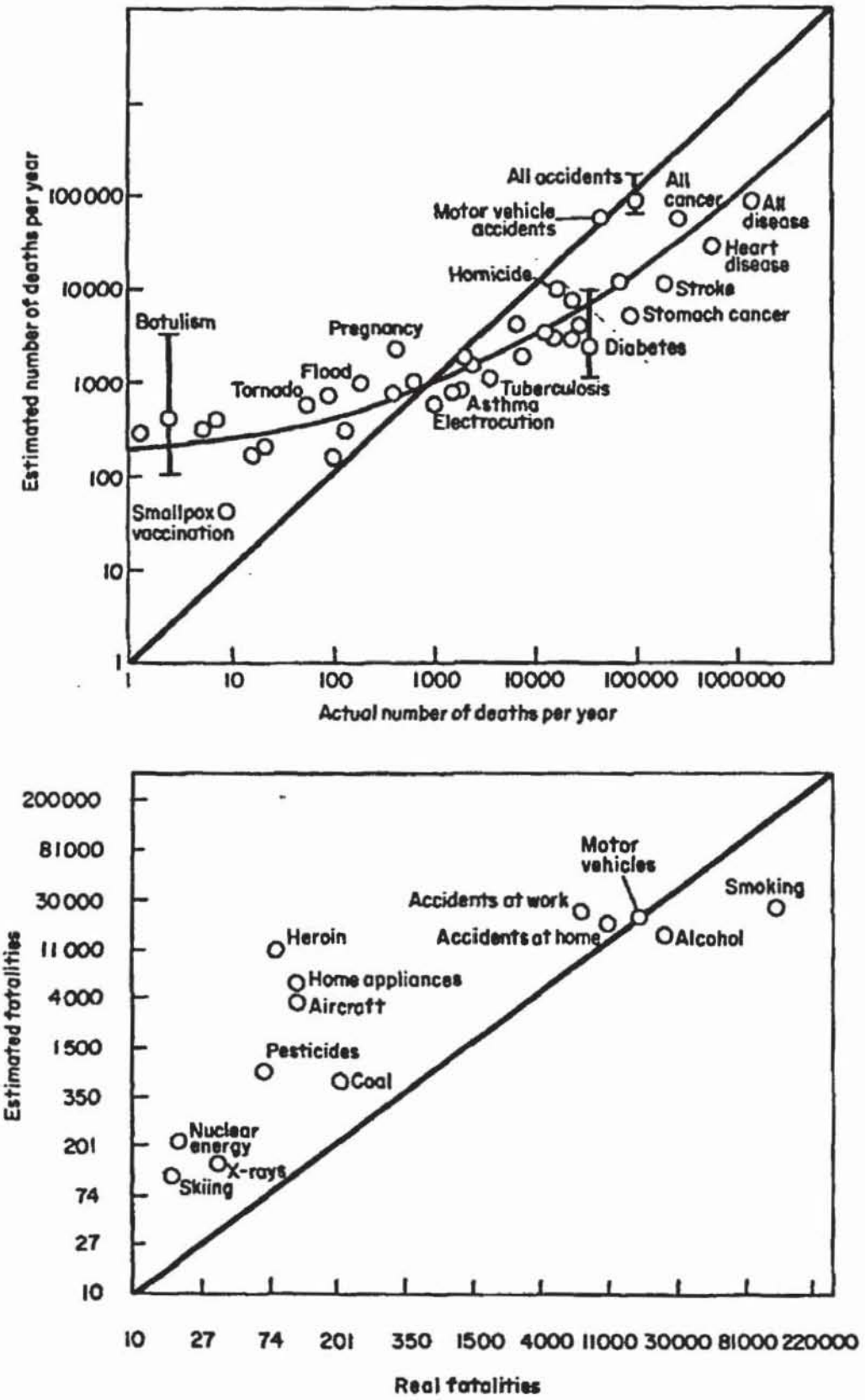

Figure 1. Comparison between perceived and actual losses per year for various health hazards: American data (top); German data (bottom)

USA and in Germany, to overestimate low risks and underestimate high risks, although the German sample tends rather to exaggerate the real figures. Nonetheless, the extent of agreement between estimated and actual values is fairly high.

Turning from the finding that risk levels and their probability in an average year are perceived relatively correctly by the public, the question immediately arises whether these parameters also determine the subjective evaluation of risks. And here a surprising result is obtained. In almost every case, analyses correlating intuitive risk estimates and estimated loss reveal no relationship between the two. This result has also been obtained by Slovic *et al.*[1,2] who found, as in the present study, a very low agreement between estimated risk level and risk evaluation, and several studies on the acceptance of medical risks have reached the same conclusions.[7] The problem of acceptance is only slighly influenced by estimates of the level of risk, but far more affected by the evaluation of the consequences of taking the risk and the motivations for accepting it.

All these studies confirm the result that perceived risk levels represent only one, possibly low, factor influencing the estimation of risk. In the case of normal averages, the risk level estimates of experts and laymen are relatively homogeneous. However, the experts consider these estimates to be a normal basis for accepting a decision, while laymen consider them to be only one weighting factor among many.

Qualitative risk properties and beliefs about risk sources

Since expected losses/year are not good indicators of intuitive risk assessment, the circumstances of the risk situation and the beliefs about the characteristics of various sources of risk become more significant. In order to demonstrate the significance of qualitative risk properties, a psychological experiment was carried out at the Nuclear Research Centre at Jülich.

In this, 37 people, who had responded to a newspaper advertisement asking for volunteers to take part in an experiment to test pharmaceuticals, were randomly distributed into two groups of 18 and 19 people. On the same day but independently, each group was invited to a neutral location (a school) and seated in a separate classroom. On each person's desk was a package containing three identical, commercially available, vitamin capsules.

The experimenter, wearing a doctor's white coat and pretending to be a physician, explained to both groups in identical words that his pharmaceutical company had developed three new capsule coatings, all of which dissolved in the stomach twice as fast as in conventional capsules. In order to achieve this, he explained, one capsule had been given a weakly radioactive coating, one a coating containing bacteria, while the third

included a ring of heavy metal which was toxic if taken in large quantities. The experimenter emphasised that the quantity of the materials contained in the coating was so small that a health hazard was completely ruled out. The capsules, he said, were filled with natural vitamin preparations so that the test subjects would be doing something beneficial for their health. In order to demonstrate the harmless nature of the capsules the experimenter swallowed all three, one after the other, in the presence of the test subjects.

Subsequently he requested the members of group I to select any one of the three capsules and swallow it. In group II the experimenter directed that the first six test subjects should take the first capsule, the second six the second capsule, and the remaining subjects the third capsule. After 15 minutes the respondents were requested to state whether they felt any ill-effects, and which of the three capsules they would prefer to purchase, provided that all three were absolutely identical with respect to the amount of risk involved and their medical effectiveness.

Figure 2 provides an idea of the different behaviour patterns between the members of group I (voluntary risk-taking) and group II (involuntary risk-taking). Two basic insights can be obtained from the data:

(a) when compared to group I, there were more than twice as many test subjects in group II who stated that they felt some kind of ill-effect after taking the capsule; this significant relationship supports the assumption that voluntary risk-taking causes less aversion than involuntary risk-taking;
(b) although the stated risk was the same in each case, the results show that in both the selection of capsules and the distribution of specific complaints, opinions about the source of risk affected preferences (probably via association of ideas) independent of any apparent danger.

Freedom of choice is just one example of a whole chain of variables which are independent of loss ratings. These qualitative risk properties are often cited as the main factors influencing intuitive risk estimation, but where Fischhoff *et al.*[3,4] found a very high correlation between intuitive risk assessment and various risk properties, in particular with respect to the severity and dread of hazardous consequences, in our surveys this was true of only a small proportion of results. Instead, the estimates of risk were affected to a much larger extent by expected benefits. Only estimates of the hazards of pesticides and nuclear energy were strongly influenced by their potential risk. Since this relationship accounts for a large part of the variation in risk evaluation, it is reasonable to conclude that sources having extreme values in terms of potential risk are perceived in terms of their high risk, while assessments of risks in the intermediate value range are more affected by the benefits they may bring.

In our studies, beliefs concerning the various sources of risk, for

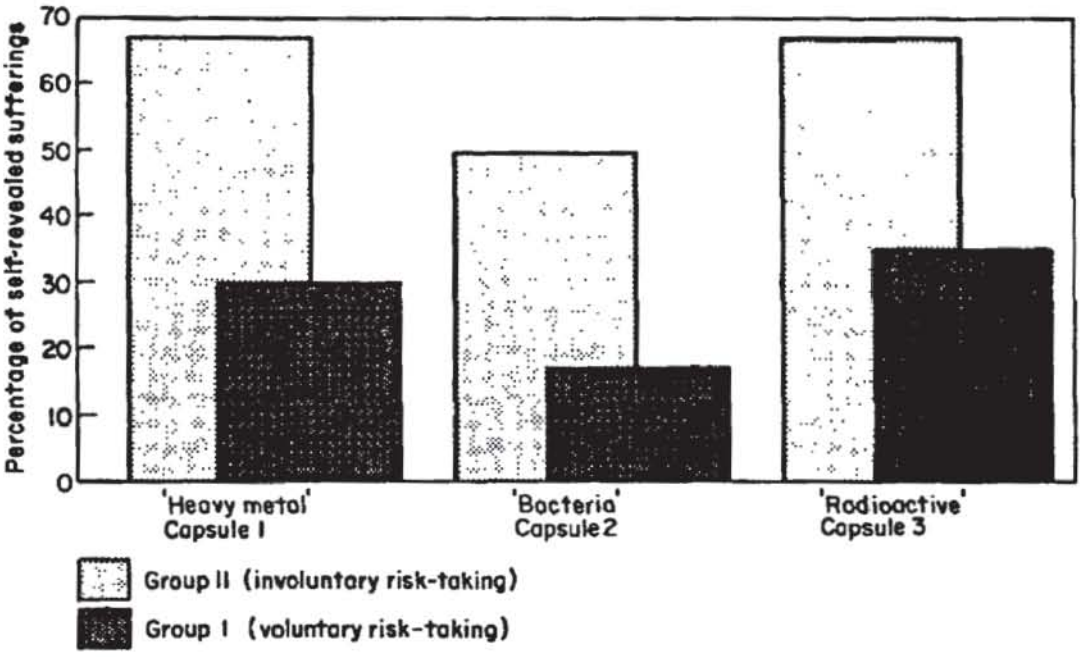

Figure 2. Influence of voluntary risk taking: members of group I could take any capsule of their choice; members of group II were forced to take the one prescribed. Psychomatic complaints (self-induced) were significantly higher in group II

example that nuclear energy will raise the standard of living, had the greatest effect on the estimated value of that risk. The same conclusion has been drawn by the Risk Assessment Group of the International Atomic Energy Agency (IAEA).

In order to investigate these particular variables, a random group of 100 people were asked to rate their beliefs about 12 different sources of risk according to 46 attributes. Using factor analysis to develop the basic patterns of these attributes, a set of comparable factors was developed which could be grouped under the following five headings:

(a) effects on the person himself or on his social environment (health, security, etc.);
(b) extent to which a person is directly affected (personal benefits or injuries, comfort, well-being, freedom, etc.)
(c) effects on economic and social welfare (employment security, social status, general standard of living, quality of life, etc.)
(d) socio-political and social values (social justice, democratic rights, equality of distribution of benefits, etc.);
(e) effects on future conditions (maintenance of economic levels, defence, security of supplies, etc.)

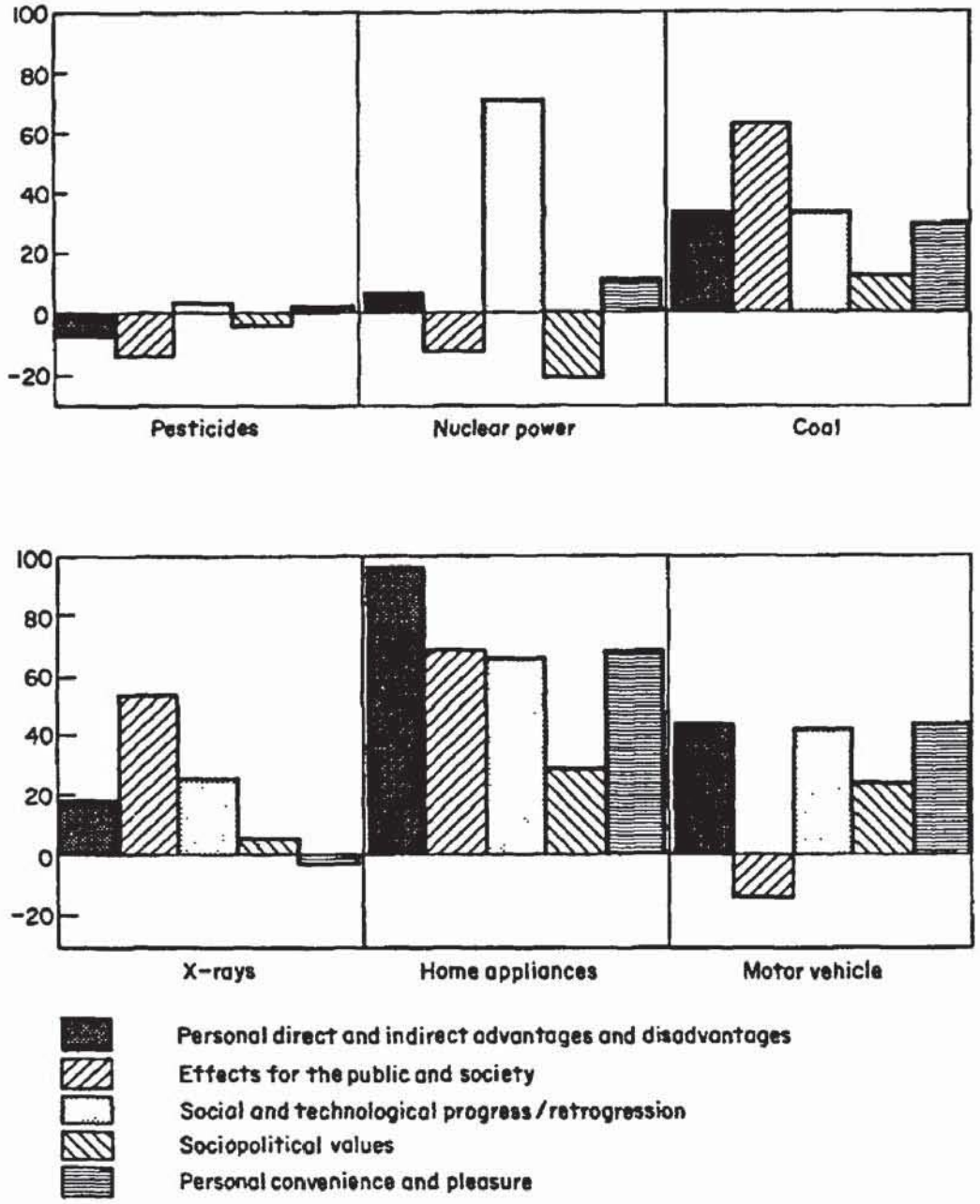

Figure 3. Importance of five belief factors with respect to estimates of the risks of various technologies

These five criteria are not all used to judge every source of risk and the significance of the individual factors differs greatly. In order to obtain an overall view of the importance and relationship of the five criteria the average values for the individual factors have been compiled for six sources of risk (Figure 3). The bars extending below the zero line in this figure show negative estimations with respect to the risk under consideration, while those above show a corresponding positive evaluation.

This graphic repesentation of the results of the survey can be interpreted in the following way.

(a) A common characteristic of the risk sources given positive values in risk-benefit evaluation is that subjective values and advantages play a dominant role (electrical appliances, cars, coal).
(b) Risk sources given highly ambivalent evaluations (nuclear power stations, pesticides) are associated predominantly with socio-political and society-related disadvantages, while health aspects and personal economic advantages are approximately in balance.
(c) A very complex structure of beliefs is found in the case of pesticides and nuclear energy. The value levels for pesticides are clearly distributed about zero, expressing an ambivalence about their perceived advantages and disadvantages. Assessments of nuclear energy exhibit a well-developed high value on the question of projected advantages and a well-developed low on the question of consequences to society and politics. On the whole, consequences for the individual are given a slightly positive evaluation in contrast to the society-related and economic aspects. These results support the theory that at present the projected advantages of nuclear energy barely compensate for the perceived negative consequences.
(d) Using energy from coal as a yardstick for comparison with nuclear energy the great difference in the evaluation of personal and society-related aspects can be seen immediately. The median for the subject-related beliefs is 26 points higher for coal than for nuclear energy; in the case of the society-related and economic values, the difference amounts to as much as 68 points. Only progress, the third dimension, is attributed more to nuclear energy than to coal.

Last, but not least, special personality traits can be revealed as influential factors affecting individual risk estimation. Overtly, persons with high risk propensity in their own life-styles estimate risks lower than persons who are adverse to risks. One trend, however, deserves special attention. Individual stimulants, such as smoking or skiing, are only classed as less acceptable if there is a conscious overall negative attitude towards risk-taking. Technological or industrial risks are considered to be less acceptable whenever there is no actual positive attitude toward risk-taking.

Attitudes toward nuclear energy

The process of risk perception has been described as an intuitive balancing of perceived attributes of the risk source and the incorporation of

qualitative properties of risks (benefits) and of particular individual traits. Expected values are just one attribute of a risk source and in no way determine the result of intuitive risk estimation. As beliefs about a risk source have been revealed as the most important factor in this respect, the structure of attitudes toward the risk source has to be investigated further.

Attitude measurement should not be confused with taking opinion polls. Polls usually refer to a temporary mood in respect of an object, whereas attitudes exhibit a structured relationship between a person and an object (or another person). Social scientists divide attitudes into three dimensions: cognitive beliefs, emotional affects and behavioural intentions. The belief system, i.e. the attributes that people assign to various objects,

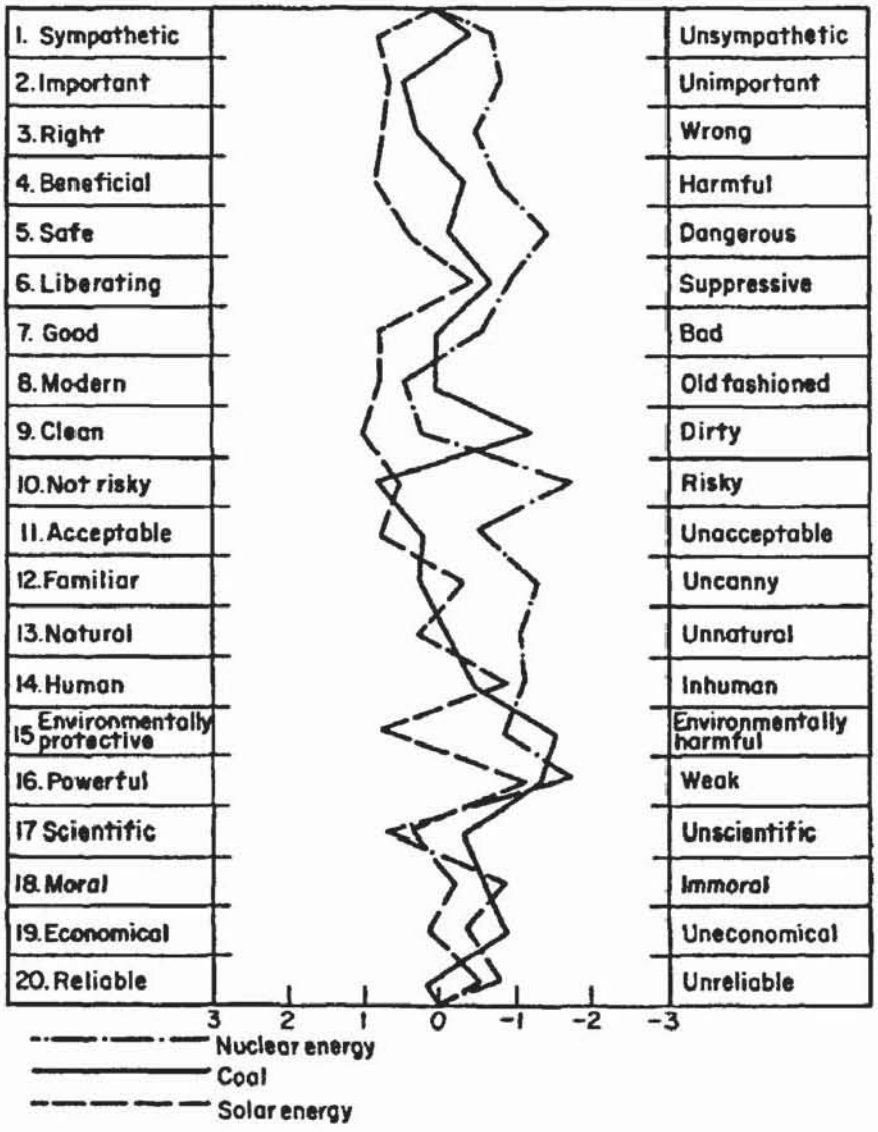

Figure 4. Semantic differential analysis for nuclear, solar and coal energy. Nuclear energy is more frequently associated with negative attributes

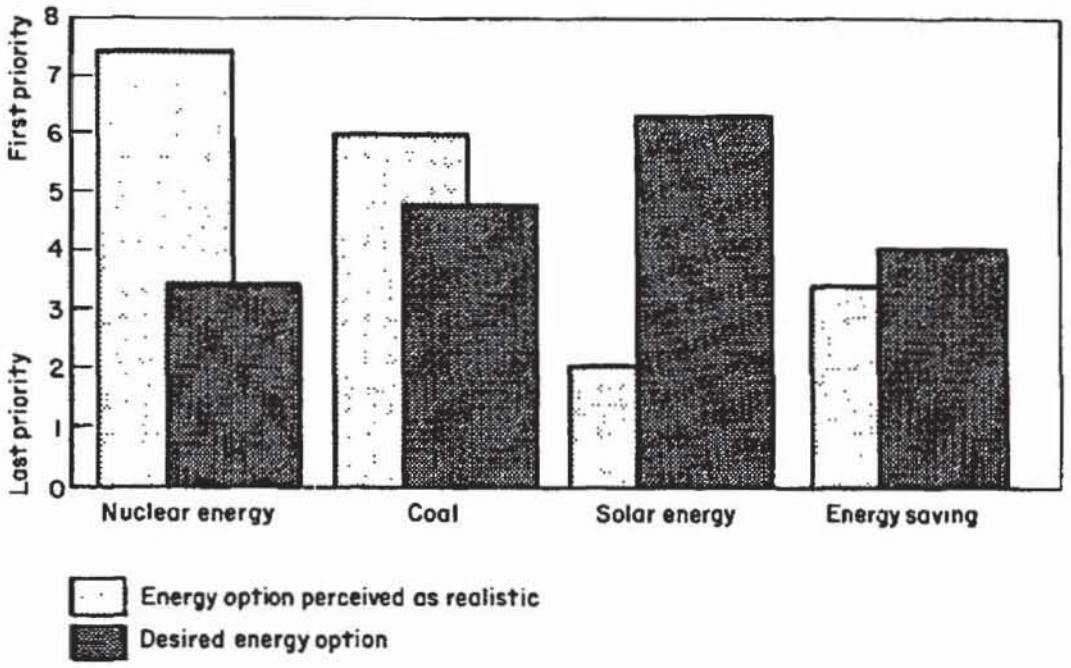

Figure 5. Discrepancy between desired energy future and perceived reality. Nuclear energy is seen as most important but least desirable for the future

has already been described. The emotional component of an attitude can be visualized by a so-called 'semantic differential'. People are asked to rate different objects with respect to symbolic characteristics and emotionally loaded attributions. The results of such a procedure are shown in Figure 4.

A profile of ratings has been drawn for nuclear energy, solar energy and coal. The three curves demonstrate that solar energy is given highly positive evaluations in all categories and that coal is also given a positive evaluation under general and analogous terms, with negative judgements only under pollution and waste of resources. However, nuclear energy is only regarded positively in the categories 'scientific' and 'modern', while it is negatively perceived in all other categories.

Differentiation between opponents and proponents of nuclear energy reveals clear-cut differences in response behaviour for the nuclear energy profile, but hardly any differences in the profiles for solar energy and coal. The lack of a link between attitudes to nuclear energy and perceptions on alternative energy sources must lead to the conclusion that both opponents and proponents intuitively prefer alternative energy production systems.

This intuitive preference for non-nuclear alternatives can also be seen by comparing the desire of the respondents to devise their own future energy option with their perceptions of reality. If the beliefs held by individuals as to what their future should be like and their expectations as to what it will actually be like are differentiated, an inversion of the order

between personal preferences and expected development is found. More than half the interview subjects were convinced that by the year 2000 nuclear energy will have become the most important source of energy, but only 20% would welcome this development (Figure 5).

The results obtained in our study clearly show that the perceived future prospects and individual preferences as to the shape of the future are certainly not identical, and may even be diametrically opposed. This contradiction is not without relevance for the political acceptance of nuclear energy. The greater the conviction on the part of the public that their future way of life is being shaped against their will and without any possibility of exercising personal influence, the more likely it is to produce political apathy and resignation or a retreat into a fragmented social structure or violent reaction.

Thus the opponents of nuclear energy believe that it is possible to live without nuclear energy power stations, but feel that this opinion is politically unrealistic. Intuitively the adherents of nuclear energy also prefer alternative energy production systems, but compensate for the negative aspects by three mechanisms:

(a) *Assignment of symbolic values to nuclear energy* (such as 'progressive', 'modern', 'prestigious', 'scientific' and 'adapted to an industrialized society'): This symbolic evaluation was a predominant feature of the euphoric pro-nuclear attitudes of the 1960s; today only older and technically inclined people associate nuclear energy with positive values.

(b) *Belief that nuclear energy may be hazardous, but is absolutely essential to the economy and future standards of living*: The perception of economic necessity was one of the central dividing lines between opponents and adherents of nuclear energy. In particular, when people developed a favourable view towards general economic values such as raising the standard of living, they rated nuclear energy as an economically essential precondition in achieving these aims. If people were more inclined towards qualitative values such as pollution control or a harmonious environment, they regarded nuclear energy not only as opposed to these values but also as incompatible with economic values.

(c) *Confidence in groups of professional proponents*: Even if people have doubts about the safety of nuclear power stations, they can develop a positive attitude towards nuclear energy, provided that they still have confidence in legal and scientific institutions. People with negative attitudes towards science in general or to the problem-solving capacity of political institutions, are usually opposed to nuclear energy or at least ambivalent.

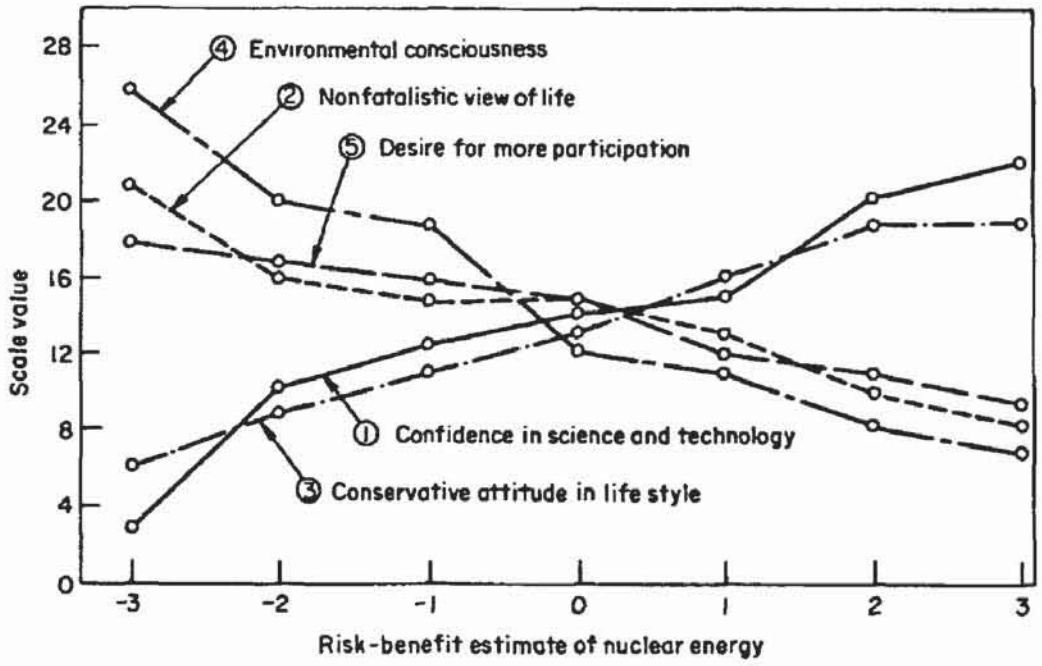

Figure 6. Risk-benefit estimation of nuclear energy as a function of five socio-political attitudes

These three findings of our survey can be well-documented by two statistical results. In Figure 6 five general attitude scales (confidence in science, politics and technology; conservatism; participation; political apathy; and environmental awareness) are shown as functions of the risk estimation of nuclear energy .

At first glance, Figure 6 supports the assumption that general socio-political attitudes significantly affect perception of the risks of nuclear energy. These findings are also supported by the high correlation with risk-benefit estimates. Low confidence in the statements of scientists and technologists, combined with a high priority for environmental protection, produce a more negative perception of nuclear energy risks at the outset. Conversely, confidence in science and technology and a low degree of environmental awareness represent an attitude which from the start tends to develop positive expected values. There is no deterministic relationship between attitudes in the socio-political field and those towards nuclear energy (as has been postulated by Dumenil *et al.*[8]), although it has not been possible to verify all possible related attitudes within the scope of a single study.

In order to investigate further the role of scientific institutions and various social and political factors, we included a scale designed to measure the credibility assigned to these institutions. The numerical data are given in Table I, which provides some interesting results:

Table I. Credibility attributed to institutions on questions of nuclear energy

Institution	Total median value	Median values Opponents	Adherents	*t*-test (*p*)
Professor at a nuclear research centre	1.44	1.88	1.47	0.00
Scientist at a university	1.72	1.88	1.71	0.03
Reactor safety commission	1.95	2.24	1.80	0.00
Federal Minister of Research and Technology	2.09	2.34	1.99	0.00
Scientist in a citizens' action group	2.32	2.18	2.50	0.00
Representative of the medical profession	2.39	2.42	2.38	0.60
Federal Chancellor	2.40	2.68	2.36	0.00
Speaker for a citizens' action group	2.60	2.39	2.73	0.00
Chairman of a utility company	2.69	2.91	2.43	0.00
TV commentator	2.70	2.77	2.67	0.18
Speaker for Social Democratic Party (SPD)	2.95	3.06	2.84	0.01
Speaker for Christian Democratic Party (CDU)	2.96	3.03	2.86	0.04
Politician	2.99	3.07	2.95	0.09
Speaker for Liberal Democratic Party (FDP)	3.00	3.00	3.01	0.93
Journalist	3.03	2.97	2.96	0.87
Manager of an industrial company	3.10	3.32	2.89	0.00
Local politician	3.12	3.17	3.06	0.15
Trade union chairman	3.20	3.24	3.12	0.10
Priest	3.56	3.37	3.40	0.64
Chairman of the German Football Association	3.87	3.84	3.68	0.01
Average value	2.71	2.80	2.64	0.01
Confidence interval	±0.23	±0.64	±0.38	

Medians; range: 1 = high credibility 4 = zero credibility

(a) Where credibility on questions of nuclear energy is attributed to anyone at all, it is most likely to be to the representatives of science and technology or of technically responsible political bodies (such as the Federal Ministry of Research and Technology).

(b) In their assessments of the credibility of scientific institutions there are only minor differences between the opponents and proponents of nuclear energy. Both groups assign the highest rating to these institutions.

(c) Central political institutions and technically competent business institutions generally occupy intermediate positions on the scale, while social institutions such as trade unions and churches, and people in certain individual social groups such as journalists, managers or local politicians, are located at the bottom end of the scale.

(d) On the basic tripartite scale of ratings, opponents and proponents differ very little: science comes first, followed by politics in general and finally the institutions of society. On the whole, however, opponents assigned lower ratings to almost all institutions than did proponents.

(e) In judging the credibility of scientific experts, opponents attributed the greatest credibility to members of universities and nuclear research centres. This is surprising because the opponents are convinced that the overwhelming majority of the staffs of these two types of institution are in favour of nuclear energy. Competent scientists engaged in a citizens' action group are given only third place by opponents (and eighth place by proponents). This was unexpected considering the opponents have closely aligned views. Economic experts, especially in private business, are given the lowest credibility potential by the opponents. It appears that they have lost their powers of persuasion.

It would appear that the adherents of nuclear energy require more support from the groups in whom they have confidence than the opponents, who are relatively 'generous' in attributing a high degree of credibility even to institutions such as the Reactor Safety Commission and nuclear research centres, which hold the opposite view to themselves. It is possible that opponents can depend more confidently on their cohesive structure and, based on this inner certainty, can be more receptive to information which contradicts their personal attitudes, while the proponents, uncertain of their inner convictions, require strong support from institutions.

Conclusion

In a situation in which both cognitive contradictions and a successive change of value judgements introduce uncertainty into people's systems of belief, studies on the perception of technology gain a special significance. Our task consisted of using the tools of empirical social research to trace the risk perception process and show how attitudes are formed. It was not, of course, possible to do this for technology as a whole: a particularly controversial topic, the use of nuclear energy, was therefore selected as an example for selective study of the determinants of risk perception.

How can we reconstruct the risk perception process for nuclear energy on the basis of these empirical results? An attitude toward nuclear energy is formed primarily as a result of an intuitive attribution process. Since nuclear energy is today associated more frequently with negative values (such as incomprehensibility, involuntariness, dread, etc.), than with postive symbols (progress, advancement and national prestige), the weighting of nuclear risk tends more towards the negative. This negative pre-evaluation should not be interpreted as an emotional bias or ambigious fear. The weighting mechanisms, such as qualitative properties or expected social consequences, are 'normal' instruments of common-sense reasoning which are reinforced by daily experience. As stated earlier, people who are in favour of economic values and assign considerable confidence to the judgement of experts can compensate for the negative pre-weighting and form an overall positive attitude. Yet this attitude structure is not very stable and needs support from professional pro-nuclear groups.

Being opposed to nuclear energy is more 'natural', on the basis of intuitive reasoning. However there are different degrees of opposition. Most people with moderately negative attitudes are not willing to act in any way against nuclear energy. They are convinced that nobody cares about their opinions and that the government will push through its nuclear programme without public consent. But there is a very effective minority, consisting of middle-class intellectuals with low confidence in scientific or institutional decision-makers, who transform their rigorously negative attitude into direct action. These people are not only convinced that nuclear energy violates their basic value structure; they even doubt the economic advantages of nuclear power.

What is the basic message which can be derived from the results of the survey? First, it appears impossible to persuade the anti-nuclear activists to give up their views and change their attitude. But one can require them to develop alternative plans for the future supply of energy which will demonstrate the consequences that would arise if nuclear energy were not to be developed.

But the main activity should be to reassure those already convinced and to continue the dialogue with those still undecided by handling the nuclear

debate efficiently. As a recommendation for continuing the dialogue between proponents and opponents of nuclear energy, we consider it necessary that the topics of such conversations should be oriented rather towards the perceived results of nuclear energy utilization than to the discussion of expected levels of risk, which are in any case little contested. At present, the following problems appear to us to be of particular relevance:

the economic advantages of using nuclear energy;
the containment and management of disasters;
loss of freedom through the need to safeguard against sabotage and terrorism;
the long-term aspects of nuclear energy utilization (e.g. storage of radioactive waste).

The negative pre-weighting of nuclear energy risks may be overcome only if the role of nuclear energy in providing for the quality of life of future generations can be illustrated more clearly.

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