Nuclear Development

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Society and Nuclear Energy: Towards a Better Understanding

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996); Korea (12th December 1996) and the Slovak Republic (14th December 2000). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consists of 28 OECD Member countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Republic of Korea, Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities also takes part in the work of the Agency.

The mission of the NEA is:

- to assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

FOREWORD

Nuclear energy is a well-established component of electricity supply in many OECD countries and is attracting renewed interest from policy makers and the public in the light of its potential role in long-term strategies aiming at alleviating the risk of global climate change and more generally in sustainable development policies. However, the implementation of nuclear projects often raises social concerns about risks associated with possible releases of radioactivity in routine and accidental situations, radioactive waste disposal and nuclear weapons proliferation.

Understanding risk perception, communicating with civil society on the issues at stake and associating the public with decision making in an effective way are essential for the future of nuclear energy. The NEA Nuclear Development Committee therefore included a desk study on those topics in its 2001-2002 programme of work with the objective of providing policy makers with fundamental findings and recommendations on the way forward to a better understanding of society and nuclear energy.

The study, based upon a comprehensive review and analysis of research work and published literature on topics such as risk perception, risk communication and decision-making theory, provides insights into key issues to be considered by policy makers in order to develop consensual decision making.

The report was prepared by the NEA Secretariat with the assistance of consultants and senior advisers. It is published under the responsibility of the OECD Secretary-General.

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1. INTRODUCTION

Background

Nuclear energy is an important component of electricity supply mixes in many OECD and non-member countries. Currently, nearly one quarter of the electricity consumed in OECD countries is generated by some 350 nuclear units in operation in 16 member countries. For several of those countries, the contribution of nuclear energy to security of supply is important, and in some cases essential, in the light of their lack of domestic fossil fuel resources and limited potential for harnessing efficiently renewable energy sources. Furthermore, a number of OECD countries consider that nuclear energy could continue to play a key role in alleviating the risk of global climate change, reducing local pollution and more globally in sustainable energy supply mixes.

The performance of nuclear energy, based upon more than 10 000 reactor-years of experience world-wide (of which more than 80% was acquired in OECD countries), is very satisfactory. Nuclear power plants in operation compete successfully on deregulated electricity markets in several countries. The number of accidents that occurred in civil nuclear facilities and led to human fatalities, or significant health or environmental damage, remains extremely low after several decades of commercial use of nuclear energy.

However, the implementation of nuclear energy projects often raises social concerns about risks associated with: potential release of radioactivity in routine or accidental conditions; radioactive waste management and disposal; and proliferation of nuclear weapons. Those concerns need to be addressed, in particular by informing and consulting all stakeholders and involving them in decision-making processes aiming towards reaching consensus on key issues.

The lack of understanding and consensus between civil society and decision makers on issues related to nuclear energy may lead to conflicting situations in some cases and will eventually result in energy policies and supply mix choices that are not optimised from the viewpoint of society as a whole. Enhanced communication between stakeholders exchanging and discussing robust information would promote consensus building and commonly agreed choices.

In this context, the Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle (NDC) decided to include in its programme of work for 2001-2002 a study on society and nuclear energy aiming at a better understanding of the interaction between the different stakeholders within the decision-making process related to nuclear energy projects. The study is intended primarily for policy makers in member countries but is expected to be of interest to all stakeholders within OECD as well as in non-member countries.

Objectives

Overall objective of the project

Integrating economic, environmental and social dimensions in trade-offs leading to decision making is essential to achieve the goals of sustainable development. In this context, it is important that policy makers develop and implement new approaches and methods in order to facilitate the involvement of all stakeholders in the decision-making process while maintaining a high level of economic efficiency.

The main objective of the project is to offer some findings and recommendations, drawn from comprehensive analyses, aiming at a better understanding of behavioural attitudes of various stakeholders towards nuclear energy. The outcome is intended as a means to develop policy and decision-making processes in the field of nuclear energy better adapted to the needs and expectations of society.

Two phases

Recognising the wide-ranging issues to be addressed within the study, it was decided to carry out the project in two phases. The first phase, described herein, includes a preliminary approach to key issues based upon a desk study, covering a review of literature and academic research on the subject matter and a compilation of public opinion surveys already carried out in various member countries. The second phase, to be undertaken within the next NDC programme of work, will build upon the findings from the desk study and focus on reviewing the experience acquired in member countries regarding consultation and communication with civil society. A range of case studies will be analysed to illustrate common issues and country specific aspects. The outcomes from

the overall project should lead to findings, conclusions and recommendations for consideration by policy makers.

Specific objectives of the desk study

The main objective of the desk study is to investigate the various issues raised by nuclear energy in the context of modern society through a comprehensive review and analysis of research work and published literature on those topics.

This report is based upon a compilation of selected published materials reflecting state-of-the-art knowledge in the field. Although some preliminary insights on key issues may be derived from lessons learnt from past experience as presented in this document, it is intended to serve as a basis for further discussions and in-depth analyses supporting more robust conclusions and recommendations.

Scope of the report

The report focuses mainly on issues relevant for nuclear energy but also covers a number of topics of broader general interest. For example, topics such as risk perception and communication and evolution of decision-making processes in modern society are addressed insofar as they are relevant for analysing relations between society and nuclear energy.

In this report, issues are addressed in the context of OECD countries but the role of non member countries within global energy markets is taken into account, as well as their importance as interested and affected parties with regard to global environmental issues such as climate change or natural resource management.

Similarly, issues related to social perception of nuclear energy in non-member countries are addressed in so far as they are relevant for future development worldwide. The sustainability of nuclear energy as a whole (including in the developed world) can, to a considerable extent, be determined by its future in the developing world. Furthermore, a future for nuclear energy in the latter has an impact on its future in the developed world, including from a public opinion point of view. Even if the public attitude in developed countries were to remain largely unfavourable, it could prove worthwhile for the industrialised world to remain actively involved in nuclear technology

development, if only to guarantee a safe and responsible use of nuclear power in the developing world.

The study covers generic issues related to society and nuclear energy and does not aim at analysing specific situations, such as nuclear power plant siting, uranium mining site rehabilitation or implementation of high level waste repositories. These are investigated in other ongoing activities of the Agency. The analysis below is based mainly on a rather theoretical approach, illustrated by examples, drawn from experience in a selected number of member countries.

Working method and structure of the report

The desk study was carried out by the NEA Secretariat assisted by senior experts in the field of sociology, psychology, risk perception and communication, decision-making theory, and energy and environmental issues. It is based on a review and analysis of published literature, national public opinion surveys and academic research in the field. It is intended as a preliminary review of key issues to serve as a background for a more in-depth analysis leading to findings, conclusions and recommendations to policy makers.

The report includes seven chapters, including this introduction that provides background on the rationale and objectives of the study. The second chapter on societal change and energy issues sets the stage for the overall document. It covers recent trends and modifications in the societal and policy-making landscape (such as economic growth, awareness of local and global environmental issues, and development of computer-based information technologies) that may affect the relations between civil society and technological development, energy consumption and production patterns and, in particular, the evolution of nuclear energy.

Chapter 3 discusses risk perception, a key issue for nuclear energy since low probability/high consequence events are viewed by the public as a major drawback of nuclear energy. The chapter includes a review of theoretical models on risk perception and illustrative examples drawn from case studies in the field of nuclear energy, e.g. implementation of radioactive waste repositories and accidents/incidents in nuclear power plants or fuel cycle facilities. The presentation of risk perception issues needs to be complemented by an analysis of risk communication, both from theoretical and practical viewpoints.

Whereas risk communication constitutes a subject matter that could deserve a chapter of its own, in this desk study we have opted for including it in Chapter 3, as well as giving attention to this topic throughout all other chapters.

Theoretical models developed in the field of risk communication received less attention than illustrative examples of risk communication experience in the field of nuclear energy because the latter, based on case studies related to various projects or events in different member countries, are considered to provide more practical insight.

Chapter 4 reviews recent trends in the decision-making process aiming at facilitating public participation with emphasis on aspects relevant for nuclear energy. Decision-making processes in the nuclear energy sector are illustrated by examples highlighting ways and means to enhance public participation, the role of legal and institutional frameworks, and various levels of involvement of different stakeholders and alternative strategies for consensus building.

Prospects for evolution and the way forward are addressed in Chapter 5 on developments in decision-making research. This chapter is more academic in nature, and focuses on institutional frameworks and alternative processes in order to conclude on ways and means to facilitate collaborative decision making within the nuclear energy sector.

The main objective of Chapter 6 is to summarise feedback from experience on public behaviour and reactions related to nuclear energy in a selected number of member countries. It is based upon the outcomes from public opinion surveys in various countries and the findings from those surveys. It highlights generic trends and specific characteristics resulting from cultural and behavioural differences, as well as contrasted situations, in terms of energy supply mixes and the role of nuclear energy.

Finally, Chapter 7 offers some preliminary findings and conclusions, based upon the information collected and analysed within this desk study. This chapter introduces the main objectives and expected outcomes from the next phase of the project.

Other relevant OECD studies and activities

Within the OECD, a broad ranging programme is being conducted on consensus building in decision making as a means for strengthening social cohesion as well as economic prosperity while maintaining confidence in public administration (OECD, 2001). The programme stems from the views expressed

at the 1999 OECD Council Meeting at the Ministerial Level that "ministers recognise their heightened responsibility to ensure transparency and clarity in policy making, and look to the Organisation to assist governments in the important task of improving communication and consultation with civil society."

Activities carried out in this context address either generic issues related to decision making involving public participation, mainly in studies conducted in the Public Management Service (PUMA), or specific issues, such as public relationship with science and technologies that are dealt with by the Directorate for Science, Technology and Industry (DSTI).

In PUMA, the work focuses on the relationship between government and citizens in national and local decision-making processes. The issues addressed include providing adequate information to the public, consulting with citizens, and encouraging public participation at various stages of the policy-making process. One of the key objectives is to support governmental efforts to strengthen public participation, transparency, democratic accountability and, ultimately, policy effectiveness, through the analysis of comparative information among member countries.

The work of DSTI aims at promoting public understanding of science and technology issues. Findings and recommendations drawn from the studies completed, and workshops held so far, include a broad recognition of the key role of scientists and engineers in informing the public and the importance of the media in the process. The ongoing activities on biotechnologies, including the use of genetically modified organisms in foodstuff, offer relevant findings in connection with nuclear energy and society in the field of risk perception, ethical issues, and trade-off between environmental protection and economic growth.

The NEA began studying specific aspects of issues related to nuclear energy and civil society two decades ago and has published a number of reports dealing with societal aspects of nuclear energy (NEA, 1991, 1992a, 1992b, 1994). Recently, the Agency has undertaken activities aiming at analysing national and local experience, exchanging information on experience and lessons learnt and building confidence of stakeholders in public decision makers and regulators. In particular a series of Workshops was held in 2000 and 2001 on stakeholder involvement in radioactive waste management (NEA, 2000) and radiation protection (NEA, 2001a) and on building trust between regulators and the public (NEA, 2001b).

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2. EVOLUTION OF SOCIETY AND ENERGY ISSUES

Introduction

This chapter addresses the relation between energy issues, economic development and environmental tendencies, on the one hand, and societal issues – among which, in particular, public opinion towards nuclear energy – on the other hand. Four main topics, somewhat interdependent but relating to different aspects of social concerns about energy, are covered below: evolution of society; global environmental concerns; economics; nuclear energy specific issues.

The links between public perception of nuclear energy issues and major social trends (e.g. changes in consumer behaviour and life conditions, societal differences and new communication technologies) are assessed. The relevance of nuclear energy is analysed in the context of addressing global environmental issues, such as climate change, and concerns raised by those issues in civil society. The impact of electricity market liberalisation and other broad economic trends on the economics of nuclear energy is investigated in order to identify how this evolution may affect the relations between society and nuclear energy. The chapter concludes with a review of key social issues raised by nuclear energy deployment including severe accident risks, radioactive waste disposal and nuclear weapon proliferation risks. The evolution in these fields that might affect public perception of nuclear energy, and hence its role in society in the 21st century, are considered.

Changes in society affecting nuclear energy

Consumer behaviour

The future of nuclear energy will be influenced by consumer behaviour and the evolution in energy consumption and use patterns. In particular, the extent to which nuclear energy will adapt to changing users' requirements will be a key factor for its future role in energy supply systems. In terms of

consumer behaviour, a number of current trends may influence the way society is considering nuclear energy.

Household preferences might play an increasing role in determining which energy options people will use, and hence which sources and technologies governments and suppliers will choose to deploy. In various countries already, consumers can indicate to power utilities what percentage of their electricity consumption they wish to be supplied by renewable sources. If, in the future, full consumer choice will be allowed, the public will be able to decide in a more direct way than before the origin of the energy they consume. Hence, they can have a very direct and concrete influence on whether nuclear energy should constitute, or remain, a share of their total energy bill, and, if so, by which amount.

Some trends seem to indicate that, for certain regions or countries at least, energy consumption tends towards more independence from grid connected supplies. Indeed, autonomous choice and self-sufficiency seem to be increasing in a number of industrialised countries, where households opt for producing part of their own electricity needs, e.g. by installing photo-voltaic panels on the roofs of their houses, or by building wind turbines in their backyards. If such trends towards distributed production are to expand and gain in importance, nuclear energy, at least based upon current generation of reactors, will be put in a position of relative disadvantage, since it is not compatible with distributed production close to domestic end use consumption. On the other side, trends to urbanisation and the ever growing size of mega-cities, in particular in developing and newly industrialised countries, as well as market opening across national boarders, are calling for large power plants and integrated networks as discussed below.

Given its intrinsic characteristics, nuclear energy, at least based upon current technologies, is not adapted to use at the scale of even large villages, not to speak of individual households. In particular the rather large size of nuclear units of present generation is more suited for use at centralised, rather than at dispersed levels. The surveillance needed to ensure nuclear safety, radiation protection and radioactive waste management is a challenge when considering small nuclear units for distributed energy production. However, some advanced nuclear system designs have characteristics, e.g. small size, passive safety features, that could facilitate their use as a distributed source of energy and change the way society views nuclear energy.

Changes in life patterns, such as people working increasingly at home via the Internet, or changes in household size and location, can have unpredictable effects on energy use, and consequently on the potential role of nuclear energy.

For example, in OECD countries there is an increasing tendency for people to move from urban apartment buildings to suburban residences as welfare increases.

This may have noticeable effects on overall energy consumption, and on that of specific energy technologies and sources in particular. On the one hand, one can argue that these trends increase energy consumption considerably, in the former case because of the increased electricity consumption of personal computers, in the latter case as a result of people possessing more apartments that need to be heated and air-conditioned. The latter case could also involve the need for more transport. This – notably in view of the societal impact global warming might have – may promote the use of carbon-free energy resources, among which nuclear energy. On the other hand, one can argue that work at home reduces the need for daily transport to the work place, thereby lowering total energy requirements. This would mitigate the need for using non-fossil energy resources.

Urbanisation and electrification

Urbanisation, already mentioned above, and electrification, have significant impacts on energy consumption, and, thereby, on energy production and distribution infrastructures. This in turn affects society views on the role of alternatives energy supply sources including nuclear energy. Urbanisation, and in particular the increasing number of very large cities surrounded by densely populated suburban areas, is a driving factor in total energy demand and the type of energy services required. Electrification leads to increasing need for generation capacity and associated infrastructures.

Nuclear energy is a concentrated source adapted to concentrated demand arising from large cities. It is less land intensive than most alternatives, in particular renewable energy sources. In areas such as large urban complexes, where space is scarce, land requirement is a challenge for most renewable energy sources and may raise social acceptance issues that could, in some cases, prevent the implementation of otherwise technically feasible and economically viable projects.

On the other hand, the implementation of nuclear power plants in or near densely populated areas raises social concerns associated in particular with aversion to risks associated with radioactivity and complexity of emergency planning in case of accident. More generally, modern society tries to avoid the implementation of industrial complexes close to residential areas. Eventually, however, the need for trade-off between benefits from energy services and

burdens from energy production have to be recognised by decision makers and other stakeholders.

Industrial development and increasing welfare have been associated in OECD countries with growing share of electricity in total energy demand and supply. Developing countries follow a similar trend with higher growth rates of electricity consumption than of total primary energy demand. Furthermore, electricity is more easily accepted by society, as a clean energy source at the end use point, than most other available energy carriers. This evolution is relevant for the future of nuclear energy since, so far, nuclear energy has been supplying mainly base-load, grid-connected electricity.

Fossil fuels, especially oil, have a large advantage today in that they can be employed both as fuel for power generation and for use in transport. This advantage is likely to prevail for some time and the increasing use of gasoline-fuelled cars, in OECD and developing countries, raises social concerns. Both local pollution and global warming concerns are calling for reducing the use of fossil fuels in the transport sector. The dominance of hydrocarbons, especially oil, in the transport sector could be reduced by the development of biofuels and/or electric vehicles. In the long term, a shift towards hydrogen systems, using fuel cells fed by hydrogen in cars and other vehicles may become a viable option. In this context, electricity may broaden its market share and nuclear energy may benefit from this evolution.

Heterogeneity and variability of public attitude

The public attitude towards nuclear energy varies from region to region. Three major global regions, characterised as the West, the East and the South have been identified as representing contrasted public views in this regard (see Bruggink and van der Zwaan, 2001). The public opinion towards nuclear energy in the West, notably regarding radioactive waste, nuclear accidents and risk of nuclear weapon proliferation, may be characterised by the words “critical” or “hesitant”. In the East, as a result of the inheritance of the ex-USSR and a situation not yet fully satisfactory in terms of safety and waste management, “apathetic” or “tired” would probably best qualify public attitude. In the Far East and South, “awakening” or “initiating”, terms that characterise the economy as a whole, seem to depict rather well public perception of nuclear energy. Regional differences in the public attitude towards nuclear energy are further addressed later in this report.

The variability of public opinion is illustrated by the evolution of public attitude towards nuclear energy in the United States (Rosa, 2001). In the early

days of the nuclear era, the US society seemed to be rather ambivalent towards nuclear energy. After the Three Mile Island and Chernobyl accidents, this ambivalence disappeared and a majority of Americans were opposed to the building of new plants. Meanwhile, however, they still continued to believe that nuclear power could be an important source of electricity in the long term.

This apparent contradiction can be understood as the result of the public's apprehension about the technology as a result of past accidents, mis-representations by the nuclear industry and a general mistrust of a number of institutions combined with a confidence in technology progress. This fundamental trust of society in the future of nuclear energy offers an opportunity for enhancing communication and explaining to the public at large the benefits and limitations of nuclear power technologies.

Beyond public attitude differences, the relevance of public perception towards nuclear energy in the national decision-making process varies widely. In the industrialised OECD countries, differences in the influence of the public on governmental planning in the energy field are small. The generally high recognition of public perception in policy making is rather homogenous. Even there, though, differences exist regarding the extent to which governments reflect public preferences in the design and implementation of energy policies. The way trade-offs between diverging views, e.g. between public preferences and national priorities, are made within governmental energy policy may affect significantly the relative emphasis placed on the development of nuclear energy and alternatives.

In most developing countries, public opinion towards nuclear energy seems to have much less relevance in government policy making. For example, governments in China or India seem, for the moment at least, not to worry to a major extent about the preferences of the large public towards nuclear energy while designing their national energy policies. As those countries will evolve, and since some of them are implementing large nuclear energy programmes, it will be relevant to continue monitoring public perception and its influence on nuclear policy in non member countries as well as in OECD countries.

Computers, information and communication technologies

The development of computers and, later, that of information and communication technologies (ICTs) has, over the past decades, had a significant impact on industrial processes, consumer behaviours and life styles. Nuclear energy, as well as its social perception, have been affected by this trend: the use

of computerised equipment is widespread in the nuclear industry and public information on nuclear energy issues relies largely on ICTs.

The social importance of ICTs may be illustrated by the evolution of information exchange mechanisms, such as written letters replaced by electronic mail, and communication modes, such as posters and information brochures replaced by websites. ICTs have changed to a certain extent communication between the nuclear industry and the public. For example, the use of on-line introspection in nuclear facilities via live "public monitoring" websites provides interested members of civil society access to first-hand, comprehensive information on the operation of nuclear facilities. At present, however, accessing this information is possible only for people that can use computers and know how to navigate on internet networks.

The use of computerised equipment has changed nuclear power plant operation from a technical point of view. In the early stages of the nuclear era, no computers were available, and reactor operation had to rely entirely on the interface between man and mechanical mechanisms. As automation and computerisation became fundamental parts of all industrial processes, the operation of nuclear power plants and fuel cycle facilities benefited from monitoring and visualisation capabilities offered by computers. Technically, the combination of computer accuracy, and human know-how and judgement has enhanced safety and performance of nuclear facilities. From a social viewpoint, however, it is difficult to assess whether trust in the reliability of safety features, for example, has been improved or not by the shift to more automation and higher reliance on computers.

Like other technologies, ICTs are likely to become more accessible and commonly used as time goes by and could complement conventional mass media, such as newspapers and television, in communicating to the public about nuclear energy. Thereby, ICTs could facilitate communication between the nuclear industry, often considered in the past as secretive, and a larger fraction of civil society. For example, ICTs can be used for publicising information reported by operators on incidents and accidents occurring in the nuclear industry under the umbrella of the International Nuclear Event Scale. As with any other communication means, the quality of the information provided and the establishment of a two way exchange flow between civil society and the industry, or other information providers, will be essential to ensure trust.

Social awareness of environmental issues

Nuclear energy, environment and climate change

Environmental burdens arising from the energy sector, at the local, regional and global level, are increasingly resented by society and, therefore, focus the attention of policy makers. Energy production and use, and in particular the combustion of fossil fuels, are responsible for the emission of particulate, nitrogen and sulphur oxides, and carbon dioxide. The atmospheric pollution induced by those emissions leads to deterioration of air quality, and eventually of living conditions, especially in large cities. Urbanisation trends mentioned earlier are increasing the share of world population affected by those problems. Renewable energy sources, such as wind, biomass and photo-voltaic, and nuclear energy could supply large shares of the growing energy demand in different regions of the world without increasing drastically atmospheric pollution. In this context, society may recognise progressively the advantages those energy sources and be more supportive of their development.

On the global level, climate change has become a major environmental issue for society and policy makers. Scientists have established with a high degree of certainty that human activities, in particular industrial development based upon extensive fossil fuel burning, are provoking an increase of the global average atmospheric temperature on Earth. Anthropogenic greenhouse gas emissions, predominantly carbon dioxide from the energy sector, are responsible for this climate change phenomenon which in turn will affect various aspects of life on our planet. A recursive relation also exists between variations in the Earth's climate and those in social structures and cultural practices (see, for example, Rosa and Dietz, 1998). This relation is an expanding subject of study in the social sciences that contributes to understanding climate-society interactions. Attitudes towards the way in which mankind provides itself with energy are part of the social structure, which is affected by global warming.

Views of experts and policy makers on the role that nuclear energy could play in alleviating the risk of global climate change vary considerably. Partly as a result of such diverging views and partly because of the complexity of scientific and policy aspects involved, the public often has difficulties to understand why and how nuclear energy could contribute to address global warming issues. Since opinions on the matter conveyed by experts, scientists and policy makers have an influence on public attitude, it is essential to provide

objective information and communicate efficiently on the potential of nuclear energy, using robust assessments based on authoritative facts, figures and analyses.

Unfortunately, controversies on the potential role of nuclear energy in addressing climate change issues are characterised by extreme positions of experts on both sides, generally associated with strong convictions on the sustainability of the nuclear option. Some experts have argued that nuclear energy may be essential for reducing carbon dioxide emissions. Therefore, they suggest that the nuclear energy option should not only be kept open but expanded significantly. For example it has been stated (Wolfe, 2001) that "If we revive nuclear energy here (in the United States), and aid in expanding its use around the world, we may save the world from environmental disasters and international hostilities". Such statements are countered by opposing opinions that nuclear energy can in no manner reduce carbon emissions (see, e.g. Storm van Leeuwen and Smith, 2001). This type of extreme position does not contribute to a better understanding of key issues, but rather may prevent relevant participation of civil society to the debate.

The present role of nuclear energy in reducing the global climate change threat can be assessed by estimating the amount of carbon dioxide emissions avoided owing to nuclear electricity generation. If all nuclear power plants in operation today would be replaced by gas-fired power plants, 300 million tonnes of carbon would be added to annual emissions, thereby increasing by 5% global energy-related carbon emissions. Were nuclear energy to be substituted by the mix of fossil fuels used today for electricity generation, the increase in annual carbon emissions would be around 8%. This may be compared with the commitments of Annex I countries under the Kyoto Protocol, i.e. a 5.2% reduction, as compared to 1990 emission levels, of greenhouse gas emissions in those countries by 2008-2012 (NEA, 2002). Since these conditions are currently far from being met, as in many industrialised countries greenhouse gas emissions are higher than in 1990, a nuclear phase-out may challenge the ability of Annex I countries to fulfill their Kyoto commitments.

However, in assessing the value of nuclear energy as an option to contribute to mitigating climate change, the burdens and risks due to nuclear energy should be taken into account and compared to those related to alternative energy sources. Comparisons between the production of greenhouse gases, and other atmospheric pollutants such as SOx, NOx and particulate, from the combustion of fossil fuels, and health and environmental impacts arising from nuclear energy are not straightforward. The difficulty in making such comparisons has been stressed in many studies (for example in the very

comprehensive analysis carried out by the European Commission on externalities of energy: ExternE, 1995 and 1998). Risk perception issues (see Chapter 3) are increasing the challenge for analysts to understand views and trade-offs on which society choices are based. Present experience, in OECD countries at least, seems to indicate that a significant share of civil society perceives the risks associated with nuclear energy as worse than those related to global warming and this is reflected in choices made in some national energy policies.

Another important aspect in assessing the potential contribution of nuclear energy to reducing carbon emissions, and thus alleviating the risk of global warming, is the feasibility and acceptability of a drastic nuclear industry expansion. Nuclear energy production would have to expand by an order of magnitude or so in order to make a significant contribution to addressing climate change issues in the medium and long term (see, for example, van der Zwaan, 2001). A tenfold increase of nuclear energy by 2100, in a world consuming three times as much energy as today, would avoid, at most, 15% of cumulative carbon emissions by the end of the century. This shows that various technologies and policy options, such as enhanced energy efficiency, de-carbonisation of fossil fuels (e.g. by capturing and sequestration of carbon), and large scale deployment of renewable sources and nuclear energy, have potential for implementing sustainable energy mixes in the long term. Furthermore, advanced nuclear technologies will be needed to support a broad deployment of nuclear energy while addressing the concerns of society about radioactive waste, safety and proliferation risks.

Whether or not nuclear energy can play an important role in the future to address global climate change and local pollution issues will depend as much on social perceptions as on technology progress. Two sides have to be considered in assessing the future of nuclear energy: the scientific/technical side and the institutional/public acceptance side (Rosa, 2001). The former has undeniably enjoyed considerable progress, notably in the field of waste management and reactor safety. The latter, however, has not evolved satisfactorily over the past decades, and has been seriously affected by the Three Mile Island and Chernobyl accidents. A key lesson learned from this past experience is that social participation and consensus building are essential for the development of nuclear energy. While contemplating a renaissance of nuclear energy, scientists, engineers and policy makers should not overlook public opinion issues, but should consider them with the same attention as technical and economic challenges.

Alternative options to reduce carbon emissions

Nuclear energy and hydropower are at present the only non-carbon options that are commercially deployed on a large scale. The expansion of hydropower is limited in many countries and regions by the lack of economically and/or environmentally viable potential. Nuclear energy could be developed more broadly on technical grounds but its expansion raises social acceptance issues. It is important in this connection to investigate the technical feasibility, economic viability and social acceptability of alternatives, such as renewable energy sources and carbon sequestration, that could play a major role in alleviating the risk of global warming.

Generally, renewable energy sources and geological carbon sequestration are considered environmentally benign by society but it should be noted that so far they have been deployed at relatively small scales, if at all. Potential negative externalities, that have been unnoticed or underestimated as long as the development of these options remained modest, could become more visible if and when they would be deployed on a broad scale. Renewable energy sources such as photo-voltaic, wind and biomass require large land areas as a result of their low energy densities. If they were developed broadly, the associated land occupation will become more evident and concrete for the public and may raise concerns. For photo-voltaic and biomass, waste production could increasingly become more obvious as they are deployed at large scales. For wind energy, arguments of landscape pollution could become important, when wind turbines will be utilised in much larger numbers than at present. As a consequence, the public perception of renewable energy sources may evolve from very positive to more neutral or even negative.

While renewable energy sources are viewed by some people as an ideal solution for solving problems of climate change since they are essentially carbon-free, they also are very often climate sensitive. The performance of renewable energy sources, such as solar and wind, tends to be dependent on stable weather patterns, so if climate change becomes inescapable, their production and use will be affected.

One of the options for carbon mitigation is to sequester carbon dioxide deep underground or in oceans. Several underground alternatives can be distinguished, such as CO_2 sequestration in depleted oil or natural gas reservoirs, deep underground storage in aquifers, its use for enhanced coal-bed methane (ECBM) production or enhanced oil recovery (EOR) and its storage in mined salt domes. Carbon sequestration seems to have numerous benefits for addressing, especially in the short term, the problem of global warming but its environmental hazards and safety risks are today largely unknown, and

potentially significant. Only when geological carbon sequestration is employed at a significant scale could these risks become apparent. Among a number of potential hazards are, for example, risks related to sudden or slow carbon dioxide gas releases from underground storage sites, as well as acidification of groundwater. The analogy with nuclear energy in this respect is the possible contamination of the biosphere in the long term and the associated public fears. Carbon sequestration, like nuclear energy, could be challenged by public perception of environmental and safety risks.

Evolution of the economic landscape

Energy and electricity market deregulation

Deregulation and liberalisation of the energy and electricity markets are affecting and will continue to affect choices of alternative energy sources and technologies for electricity generation. The objective of deregulation is to enhance the overall economic efficiency through free competition ensuring that consumers benefit fully from market mechanisms. In the electricity sector, deregulation also has major consequences for investors and operators. The economic risks associated with up-front investments in generation capacity are increased by the absence of regulated tariffs and uncertainties on future demand. Therefore, market deregulation raises a challenge for capital-intensive technologies such as nuclear energy, but on the other hand it offers opportunities to least cost options.

The performance of existing nuclear power plants in competitive deregulated market has proven to be very good. With low marginal production costs, nuclear units can compete favourably with alternatives on spot markets and their high availability factor is an additional advantage. Nuclear power plant operators have used several means to enhance their revenues through higher production rates as well as lowering their fuel and operation costs. Furthermore, lifetime extension of existing nuclear power plants provides the opportunity to continue to generate relatively low-cost electricity. The characteristics of nuclear energy in terms of competitiveness, and the way the public and governments view it, are essential for the future of nuclear energy. By demonstrating to consumers that nuclear energy can be competitive, existing nuclear power plants can play a significant role in the social acceptance of nuclear energy programmes for the future.

Although a general trend to market deregulation prevails, the awareness of environmental issues and the progressive recognition of sustainable

development goals in energy policy making, not to mention concerns about security and reliability of supply, could lead governments to re-introduce some regulation. Public opinion may become a stronger force if government regulations are enacted to create favourable market conditions for renewable or non-carbon emitting energy sources, while penalising fossil fuels. This will induce companies to follow explicit marketing policies in line with opportunities created by public decisions. Under such conditions, public opinion may reinforce itself through restrictive regulation of the market place. It is difficult to predict what the effects of such a tendency may be on nuclear energy, since its advantages will be confronted directly with its disadvantageous characteristics in an *ex ante* unknown fashion. One of the major challenges for nuclear energy, however, will in any case be to establish an open and informed base for public information on policy issues.

Fuel prices

The volatility of hydrocarbon prices on international markets raises issues of long term optimisation in the electricity sector which is characterised by high investments, rather long construction times and relative inflexibility of its production and distribution infrastructure. Adaptation to rapidly changing market conditions is indeed difficult for electricity generation and transmission companies.

Nuclear energy, on the other hand, provides a guarantee of cost stability to electricity producers since its generation costs are rather independent of fuel prices. Only a small part of total generation cost derives from fuel (uranium) cost in the case of nuclear electricity, whereas for coal and natural gas fuel accounts for at least half of total electricity generation costs.

Public attitudes towards nuclear energy could evolve if the prices of gas would increase drastically owing to demand growth and/or political difficulties similar to those that resulted in several oil crises in the recent past. The price stability and security of supply offered by nuclear energy can provide countries with some guarantee of energy independence and may be an important factor in enhancing public support. This may be especially advantageous when limited amounts of domestic fossil resources are available.

Internalisation of environmental externalities

The future competitiveness of nuclear energy will in part be determined by the extent to which the environmental externalities of all energy sources will

be internalised in energy prices. So far, the nuclear energy industry has gone further in internalising negative externalities than its fossil fuel counterparts. This can be seen, for example, from the fact that the estimated cost of radioactive waste disposal is accounted for in nuclear electricity prices, whereas carbon emissions for fossil fuel use are generally not reflected in electricity prices. It has been shown that the competitiveness of nuclear power plants versus fossil-fuelled plants can be enhanced if the costs of such externalities as solid waste arising and atmospheric emissions, both for carbon and non-carbon alternatives, are integrated in energy prices (see, for example, ExternE, 1995).

External costs of electricity include in principle all the costs associated with damages from the entire generation chain not borne by the producer but by society as a whole. They are difficult to estimate in a reliable and comprehensive manner and even more difficult to value in monetary terms. External costs can vary widely depending on the energy source considered and are influenced by generation technology, fuel origin and plant location. The public perception of various negative externalities of energy use, especially those of different types, such as consequences of carbon and radioactive emissions, is likely to be time-dependent and dynamic in nature. Similarly, public attitudes towards the two different options to deal with the environmental burdens – that is, concentration and confinement (like with radioactive waste) and dilution and dispersion (as with carbon emissions) – may change in time.

Whereas significant progress has been made in many countries on measures to reduce emissions of sulphur and nitrogen oxides and particulate, carbon emissions are today almost not subject to public regulations. The internalisation of various negative environmental externalities of fossil-based energy sources, for example in the form of taxes levied on global carbon emissions or local and regional environmental pollution, would increase significantly their price for consumers. The external costs of nuclear energy, resulting mainly from the long-term impact of very low residual radioactive emissions and damages in case of a low-probability/high-consequence severe nuclear accident, are very low. However, risk aversion and the public perception of the nature and level of external costs may be as important, or more, than their estimated value based upon physical and economic data. Public perception will most likely be the ultimate determinant for choosing technologies, because it exerts a strong influence over national energy policies (see, e.g. Radetzki, 2000).

Man-made and human resource requirements

Infrastructures

The existing and expected future technological infrastructures will determine to a large extent the respective roles of fossil fuels, renewable energy sources and nuclear energy. In this respect, the impact of global warming on society, and hence infrastructures should not be overlooked. The impact of energy systems on society is not simply the sum of the environmental and economic effects of individual systems. The impacts of a particular energy option have to do, for example, with the relation between the energy system and other branches of economic activity. Some impacts go beyond the separate contributions of different energy sources. They might be related, for example, to the complex technological infrastructures required for maintaining and operating a particular energy system, as well as guaranteeing its continuity (see Bruggink and van der Zwaan, 2001).

The type and size of energy production, distribution and use facilities associated with a particular alternative significantly affect society and infrastructures. A decentralised energy supply system will necessitate a different type of technological infrastructure than a highly centralised one. A society based on a highly diversified mix of resources will require a different set of skills than a society reliant on a more limited number of technologies and resources. Choices between different energy alternatives have different impacts on the vulnerability and flexibility of societies when faced with rapidly changing circumstances or extreme conditions.

Although the corresponding infrastructures are fairly separated, the applications of nuclear energy outside the electricity sector, i.e. nuclear weapons and use of isotopes mainly in medicine, remain interconnected in the minds of most members of the public. The perceived association of military uses and the risk of weapon proliferation with peaceful applications of nuclear energy is a key issue for assessing social risks and benefits of nuclear technologies.

Human resources

The infrastructure supporting the energy sector includes not only the physical equipment needed for transportation, distribution and storage of energy, but also the human skills and institutions required to ensure reliable and safe operation of energy production plants and other facilities in the sector.

Regarding human resource infrastructure, an important factor in decision making regarding future energy option choices concerns the degree to which the desired and necessary skills have multiple uses. Biomass, for example, requires knowledge and skills that could be productively employed in replacing fossil by chemical biomass feed-stock in the chemical industry. Therefore, even if biomass energy would not be broadly deployed, the human infrastructures resulting from its development could be efficiently used for other applications.

Highly qualified manpower is required to support nuclear energy and should remain available throughout the lifetime of nuclear power plants and fuel cycle facilities. Adequate staffing is a social concern and a key element for building public confidence in the reliability and safety of nuclear energy.

The Convention on Nuclear Safety states that its is essential that "… sufficient numbers of qualified staff… are available for all safety-related activities …". Regardless of whether new nuclear power plants will be built, both regulatory bodies and industry will be in need of qualified staff to preserve the present knowledge base (NEA, 2001d).

Maintaining nuclear competencies in regulatory authorities and the nuclear industry raises a challenge in the light of the current age profile of staff in the nuclear energy sector and of the low number of students graduating from courses in nuclear science and engineering. This could result in a loss of much of the present nuclear expertise due to retirements over the next decade or so and the absence of young professionals who could fill the vacancies.

If no action is taken to redress the decline in nuclear student numbers, a shortfall between supply and demand for graduates could reach such critical proportions that much of the present knowledge in some countries could be lost. Many experts and bodies recommend that, if nuclear energy is to keep an importance for at least some share in power production, government agencies should take the lead in the immediate designation of national committees, comprising regulators, operators and educators, capable of ensuring that essential education and training facilities are identified, and that actions are taken in due course to maintain their long term viability.

Nuclear energy issues of social relevance

Society is especially sensitive to some issues that are specific to nuclear energy: radioactive waste; nuclear safety; and nuclear weapon proliferation. The risks, real or perceived, raised by nuclear energy are driving factors in public perception and could determine to a large extent the future deployment of

nuclear energy systems. In this connection, one of the challenges facing governments and the industry is to prioritise within nuclear energy R&D programmes between projects addressing technological issues and those focusing on issues of social importance. The core question is whether advanced technologies could restore public confidence in nuclear energy, or whether social confidence should be ensured first before considering the design and development of advanced nuclear energy systems (see, e.g. van der Zwaan, 1999). Furthermore, communication about nuclear energy issues is a challenge in itself owing in particular to the complexity of the technology and its risks as described above.

Radioactive waste

Issues raised by radioactive waste in relation with public perception and acceptance cover management and disposal approaches in place or under consideration for all types of radioactive waste arising from nuclear energy use, and their economic and financial impacts. However, public concerns focus mainly on the management and disposal of long-lived, high-level waste since current practices have demonstrated already the technical and economic feasibility of managing safely low-level waste, and final repositories for this type of waste are in service in many countries. On the other hand, as a result of public concerns and lack of social confidence in the technology or approaches proposed by governments and the industry, the implementation of high-level waste repositories has been delayed in several countries. However, recent progress in this area, in Finland and the United States in particular, indicates a move towards enhanced public understanding and support.

There is a high level of confidence among the scientific and technical community engaged in the field that geological disposal of radioactive waste is technically safe, and that the technology for constructing and operating repositories is mature enough for deployment (NEA, 1999a). It is recognised, however, that further refinement, testing, demonstration, implementation and quality control under reference conditions are still needed to demonstrate fully the feasibility of geological repositories.

Alternative approaches, such as long-term surface storage followed by partitioning and transmutation (P&T) of minor actinides, are being investigated as potential components in an overall radioactive waste management strategy. Partitioning and transmutation of long-lived nuclides could reduce the radio-toxicity of waste sent to repositories. Although it does not remove the need for repositories, it might mitigate the unfavourable public opinion towards radioactive waste. Also, the establishment of regional radioactive waste

repositories, that could provide economies of scale as well as improvements regarding global efficiency and safeguards, could be considered. Such an approach clearly needs social consensus on an international basis and requires a decision-making process involving extensive stakeholder participation.

The public does not necessarily share the high level of confidence of experts in the feasibility of safe disposal of radioactive waste over very long periods of time. This may be due to the fact that the time horizon over which security of waste disposal needs to be assured is much longer than the time frame over which people's concerns and imagination stretch, as well as to the uncertainties inherent to the very long term. Society has reservations towards committing irreversibly to an action whose consequences are not fully understood. Lack of confidence in waste disposal by part of the public may also be connected to a lack of confidence in other aspects of nuclear energy, such as the safety of power plants, or opposition to some nuclear power institutions. It can even be connected to a lack of trust in scientific developments in general or to technological fixes to problems faced by mankind. Moreover, strongly expressed opposition by a minority of scientists and engineers has perhaps given an impression of a large divergence of views in the technical community.

Therefore, one of the major challenges currently faced by national waste management programmes is to understand the concerns of stakeholders, communicate effectively and share practical experience from consultation exercises and public decision-making processes (NEA, 1999b). Establishing appropriate intermediaries between the public and policy makers, on the one side, and the technical community and scientists, on the other side, is especially important. Today, it is better understood than a couple of decades ago that the issue of long-term waste management has not only scientific and technical, but also ethical, social and political dimensions. The acceptability of geological disposal can be obtained, at a societal or governmental level, only after consultation with a range of relevant organisations and taking account of public views.

A step by step approach, where stakeholders are provided opportunities to interact as early as possible and throughout the process of repository development might allow more public involvement in the decision-making process. The process by which proposals are brought forward could thus be better trusted, and decisions could be made that are sensitive to specific local concerns. Still, universal support is probably not a realistic aim. As for any project that is controversial among part of the population, an appropriate societal decision-making process will be necessary. Waste management

institutions must fulfill their responsibilities to engage in an open debate on waste management, in addition to develop technical and safe solutions for geological disposition. Overall confidence must be developed in a much wider audience if a decision to implement disposal is to be acceptable: confidence of the technical community is necessary, but not sufficient. Governments will be responsible for making decisions regarding waste disposal that meet with an appropriate level of public support, and for providing the framework in which the necessary actions can be taken.

Financial and ethical aspects are very important in long-term radioactive waste management and disposal policy. The current generation, which has benefited from the nuclear energy produced, should provide future generations the means to dispose permanently of radioactive waste. Deregulation of the electricity market affects the entire nuclear fuel cycle, including the organisation of waste management. All these considerations raise issues concerning how best to achieve confidence and consensus regarding the economic, and ethical aspects of waste management strategies as well as political, technical aspects.

Reactor safety

Seeking to enhance the present level of nuclear safety by improving the effectiveness of regulatory bodies is seen as one of the ways to strengthen public confidence in the regulatory systems (NEA, 2001e). This constitutes one of the cornerstones of creating trust within the large public. In the past, accidents and incidents with various levels of impact on public health and the environment have provided the main impetus for regulatory change. Major changes were made following accidents that occurred at Three Mile Island and Chernobyl. Consequently, much of the required regulatory change has been achieved already, although continued improvement is mandatory as illustrated by more recent incidents or accidents, e.g. Tokai-Mura in Japan.

Today, however, factors other than incidents also play a role in regulatory reform. Economic factors such as liberalisation and deregulation of the electricity market, as well as technological progress like the application of passive safety properties and the development of innovative reactor types, urge for further review and adaptation of the regulatory framework. The requirements for openness and accountability add importantly to the need for a continuous evolution of the way the nuclear industry is controlled and regulated.

When public support for nuclear power declined and concerns about nuclear safety increased immediately after the Chernobyl accident, it was hypothesised that "these large changes [toward increased opposition] in public opinion are likely to be temporary" (de Boer and Catsburg, 1988). This "rebound hypothesis' underlined earlier similar observations following the Three Mile Island accident (Freudenburg and Rosa, 1984). More recent analysis, however, seems to seriously challenge the rebound hypothesis: trends in long running time-series indicate long-term unfavourable attitudes towards nuclear power (Rosa and Dunlap, 1994). Extrapolating past perception tendencies, the public opinion effects of the Three Mile Island and Chernobyl accidents are likely to be felt for a very long time to come (Blok *et al*., 2000).

Moreover, if there would be another accident of the scale of Chernobyl, that is, with a significant exposure of a large population, and with a cloud of radioactivity spreading over large parts of an entire continent, this would most likely imply the end of nuclear energy. The Chernobyl accident has had such profound and pervasive consequences on the perception of the public on nuclear energy, that another similar accident will probably have devastating consequences on public opinion. Ensuring safety everywhere in the world is therefore of utmost importance. In this connection, international co-operation aiming at harmonising safety standards at levels equal or higher than those already achieved in most OECD countries is a prerequisite for social acceptance of nuclear energy.

Safety is dealt with differently from country to country and communication with the public about safety can be of a rather national nature. In Finland, for example, questions from the public concerning nuclear matters related to power plant operation can be answered on a day-and-night basis. In the United Kingdom, public hearings exist that are accessible to everyone interested, allowing people to raise questions related to nuclear facilities. In France, the "*Comités locaux d'information* (CLI)" exist, gathering people – through membership – with all sorts of backgrounds, and giving them the opportunity to address issues concerning the nuclear facilities in their neighbourhood. Countries can probably learn extensively from each other's safety communication experiences. Exchange of these experiences and integration of the various national communication programmes can benefit the information of the public in matters regarding nuclear safety.

Nuclear proliferation

Nuclear proliferation risk is a major concern for some specialists and policy makers, however, in most member countries it ranks rather low in the

concerns of society at large according to opinion polls (see Chapter 6). If nuclear energy is not expanded significantly beyond the current, largely industrialised, countries, the development of a new generation of reactors more resistant to proliferation of nuclear materials and/or technologies, probably will not render public opinion significantly more favourable. If, however, nuclear energy is largely expanded in the future, and many more developing countries implement nuclear power plants, then reducing risks related to nuclear proliferation may become important, also vis-à-vis the public perception of nuclear energy.

At present, the potential use of nuclear technologies for military purpose provoke unfavourable sentiments of part of the public towards the civil use of nuclear energy in some countries. Whereas nuclear power plants and nuclear explosives have very distinct properties, they rely on similar scientific basis and use similar materials and technologies. Civil and military nuclear technologies are not two entirely distinct entities and this have contributed to mixed feelings and created an unfavourable image of nuclear energy in some parts of society.

Proliferation risk and society concerns in this regard place constraints on nuclear power deployment throughout the world. While it would be wrong to believe that quick-fixes exist for the problem of proliferation (see, for example, Sailor, 2001), the Non-Proliferation Treaty (NPT) and the comprehensive safeguards regime, implemented worldwide under the IAEA umbrella, have proven to be effective in detecting and deterring diversion of nuclear material or technology for non peaceful applications. Furthermore, the development of a new generation of reactors offers opportunities for enhancing intrinsic proliferation resistance and facilitating the safeguards controls. Past experience and ongoing R&D provide confidence that proliferation risk can be mitigated and reduced to a level acceptable by society in the context of a stringent and powerful international safeguards regime.

Communication

The evolution of nuclear power programmes illustrates the implementation of a technology that, over the past decades, has encountered the insurmountable barrier of gridlock (Rosa and Clark, 1999). Gridlock can, in this sense of the word, be characterised as a condition where technological policy has faced major obstacles, due to an emphasis on hardware and technological fixes to the neglect of citizen concerns. Social scientists recommend that such technological gridlock can be resolved by democratising technological decision making; that is, citizens must get the opportunity to become engaged more fully. The success in accomplishing this will importantly depend on regaining

the public's trust, as well as the designing of new institutional mechanisms for facilitating democratically based technological decision making.

Appropriate communication is a challenge and an opportunity for the future of nuclear energy. In the past, many mistakes have been made in this respect, mainly due to the secrecy and the arrogance that characterised the nuclear energy sector. The secrecy resulted largely from the initial links between civil and military applications of nuclear energy. The sense of superiority of scientists in the field, and the pride with which nuclear energy was presented, came essentially from the excessive enthusiasm of a generation which discovered/invented a truly new energy source. Furthermore, the establishment of a dispassionate debate about nuclear energy is more difficult owing to the use of nuclear issues by the green lobby and political parties as a powerful vector to draw votes.

There is basically no lack of dialogue now, but the communication switch probably has occurred too late, so that the nuclear industry remains surrounded with suspicion. The way forward might involve placing more emphasis on comparative assessment of risks, burdens and benefits of nuclear energy and alternatives. Perhaps, normal reactor operation emissions should be further put into perspective with accidental emissions, and the public ought to be better informed about the relative proportions of natural versus man-made artificial radioactivity. New information technologies, among which the Internet, could play an important role in facilitating communication about nuclear energy issues.

Communication is part of good governance, that is, policies designed on the basis of reasonable decisions that are well communicated and discussed with the public (OECD, 1998 and 2000). Whether fully rational or not, public opinion is a primordial determinant in future energy system choices. Support of society is essential for nuclear energy to play a role in future energy supply mixes. Adequate communication with society as a whole and with "opinion drivers" is essential in this regard. Recognising that, throughout history, necessity has proved the best vector for acceptance of new technologies, the benefits of nuclear energy in terms of economic development and environmental protection may become key factors in societal perception of nuclear energy.

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3. RISK PERCEPTION AND COMMUNICATION

Introduction

This chapter seeks to explore the nature of risk perception by the public in relation to nuclear energy. It touches also on issues related to risk communication, which are referred to in several other chapters of this report. First, rather formal definitions of risk, risk perception and risk tolerability are developed. Second, since a lack of public acceptance of technical, i.e. quantitative, approaches to risk assessment is currently being recognised, the evolution to a more qualitative presentation of the concept of risk is introduced.

The chapter starts by a summary of the current scientific definition of risk, as well as its – often differing – public perception. It puts ideas about the concept of risk in a historic perspective, and states that controlling, managing and understanding risks have become necessary conditions of life, especially in today's modern society. It underlines the relevance of understanding the so-called tolerability of risk, especially in cases related to the nuclear power industry, when one attempts to develop more technically and scientifically oriented assessments of risk. It sets out that a mere reliance on the technical approach to risk generally has not been found comprehensive enough. The existing discrepancy between the quantitative assessment of risks and the more qualitative public perception of those risks is analysed. A number of key factors – trust, voluntary choice, control, benefit, knowledge, gender, and catastrophic potential – that affect the public perception and acceptance of given levels of risks are identified. Finally, the chapter addresses more directly the perception of risks originating from nuclear energy production and use, and puts these risks in perspective with those related to other aspects of daily life.

Risk and risk perception

Evolution over time of the concept of risk

The scientific definition of "risk" is the expression of the compound outcome of the probability of an event and a particular hazard, where hazard means the potential to cause harm to health or environment:

Risk = probability x hazard.

Bernstein (1996) cites Hacking (1975) on the perception of risk, quoting from *Logic, or the Art of Thinking* published by the Port Royal Monastery in 1662: "Fear of harm ought to be proportional not merely to the gravity of the harm but also to the probability of the event". This is perhaps the earliest reference to an expression of risk being the product of both harm and probability.

The public perception of risk, however, can differ from its scientific evaluation. For example, the case of a high probability (e.g. that it will rain in April) multiplied by a likely trivial hazard (e.g. that the garden will be over-watered) is seen by the community as a low risk. The reason for this is that the comparative hazard is low, although the probability is high. Inversely, the remote probability of being fatally struck by lightning, which is one in ten million per annum in the United Kingdom (Trafford, 1999), is seen as a high risk. The reason is that the comparative hazard, the possibility of death, is high, although the probability is low. The latter risk is therefore one that most individuals would circumvent if given the option.

In-depth discussion of public risk perception points out that there has been an evolution in the acknowledgement and understanding of risk over time. The modern conception of risk has some relation with the Hindu-Arabic numbering system, which reached the West seven to eight hundred years ago. The serious study of risk probably began during the Renaissance, when people broke loose from the constraints of the past and subjected long-held beliefs to open challenge, at a time of religious turmoil, nascent capitalism, and a vigorous approach towards science and the future (Bernstein, 1996).

The mathematical perception of risk, based upon the probability and ranking of a particular hazard, however, is relatively new to society. As the dialogue between specialists in the field evolved to accommodate developing theories and greater complexity, so too has the disparity between the science of risk and its public understanding increased (Wynne, 1996). The mathematical

expression of risk for some hazard as being e.g. $1x10^{-5}$, is incomprehensible to the public, whereas the phrase "smoking is hazardous" has some immediate cognition.

Risks in modern society

Beck (1992) plots the evolution of the risk profile of individuals and societies as they move from the pre-industrial to the industrial era and increasingly base their decisions on technico-economic factors. He concedes that with industrialisation the traditional risks of infant mortality, famine, epidemics or natural catastrophes have been continually reduced but he argues that they have been replaced by new risks arising from, for example, nuclear power, chemical factories and biotechnologies. Adams (1996), citing Wildavsky (1988), in part counters Beck's view of "the darker dimension" of risk in a modern industrial society. He comes to the conclusion that there is "overwhelming evidence that economic growth and technological advance… in the last two centuries have been accompanied by dramatic improvement in health – large increases in longevity and decreases in sickness."

Indeed, moving to a less industrialised society likely would not reduce the overall risk to society if health and mortality is a relevant measure (Duncan, 1999). If lifetime expectancy is taken as an indicator of human welfare, risks of modern industrialised society are outweighed by its benefits (Livi-Bacci, 1997). It could be argued also that these new risks to society are offset by the rewards of health, energy, education, travel, comfort and entertainment.

Until the twentieth century people believed that hazards in their environment remained largely out of their control. If a person's existence relied upon working in a deep coal mine, then there was little alternative to accepting the hazards of that industry for him, his community and the environment, and barely any opportunity to escape. The twentieth century brought a greater freedom of choice of working environment and an improvement in working conditions largely due to the activities of organised trade unionism. Furthermore, large-scale population migrations facilitated decisions to change job and lifestyle taking into account, to a certain extent, individual risk perception and acceptance level. The industrial revolution that brought the change to the risk profile also provided the resources to counter some of the traditional risks such as famine and disease (Duncan, 1999).

Risk and decision making regarding risk are an element of life faced by all persons each day of their lives. Indeed, it can be said that managing risk is a

necessary condition of life. Many, if not all, ordinary activities carry with them risks that are implicitly or explicitly acknowledged and considered many times each day by each of us. In transportation, we routinely decide whether or not to drive cars when it is common knowledge that tens of thousands of persons perish each year due to accidents with this mode of transport. Who, when boarding an aircraft, doesn't consider the potential for a catastrophic accident, like the last one we vaguely remember occurring in the not so distant past? Each of us faces decisions on what types and sources of food and water should be consumed and what potential contaminants and pollutants they may contain. And when we light up the cigarette, do we not at some point recall the potential implications for our health and to what degree this cigarette will increase our risk for any one of the myriad effects attributed to it? Should we wear sunscreen? Is radon present in my home? Will it rain and should I wash the car or put the laundry out? What are the long-term effects of taking those newly developed drugs?

In a nutshell, in modern industrialised society, people are immersed in ubiquitous risks. Risks impact on individuals when eating, sleeping, travelling, working and certainly on vacation. Daily decisions involving risks abound. Whilst these risks are well known and quantified by experts, they are not necessarily recognised or quantified in a similar way by the public. The general population is more inclined to accept risks without specific conscious decisions on its part. If such risks are not subliminal, then at least they are tolerable. We might accept this as the *ubiquitous risk profile* of our time (Duncan 1999). It may also be in the mind of the individual that he can load the dice in his favour by eating less beef, ventilating his house to reduce the radon content and by driving his own car when travelling rather than travelling with an unknown driver.

In addition to these daily risks, there are other risks that the public is sometimes asked to consider and make decisions about, such as, siting of manufacturing plants, power plants, waste management facilities, schools, health clinics, parks and recreational facilities. These decisions usually receive special and concentrated attention as the decision process unfolds, because of their infrequency and magnitude of potential impact. It is these extraordinary decisions regarding risk, as for example those associated with nuclear energy, that engender the greatest attention and, ultimately, have driven research on how the associated risks can be defined and how they are perceived. Results of the research have been and continue to be used to refine the processes used to aid in making equitable decisions regarding risk.

Understanding and perception of risks

As mentioned above, mathematical formulations of a risk are not always consistent with the way people evaluate that risk. It has been stated that "For the public at large, however, the meaning of risk which prevails is that of a threat to people or things to which they have emotional attachment" (Poumadère and Mays, 1995). Furthermore, an important distinction exists between the value attributed to a risk by society depending upon whether it is voluntary or involuntary (Wynne, 1997). It should be noted also that an involuntary risk may be offset by a certain reward (Duncan, 1999).

The current debate on risk refers to a certain extent on the objective assessment of risk. Often, however, such assessments are rejected by society. Therefore, risk measurement methods should be proposed that take subjective and perceptual values into account. Risk assessments on long-term complex environmental issues often are based on assumed or best-guess probabilities, not on certainty. The expert's expression of risk, particularly when small risks are considered and when they are expressed in mathematical terms, is often unintelligible to a lay audience.

The view that the lay population does not comprehend numeric expressions of risk has been reinforced by witnesses to the Enquiry into the Management of Nuclear Waste, conducted by The House of Lords Select Committee on Science and Technology in 1998. The following citation from Professor Wynne (Lancaster University) captures the opinion of some experts in the field: "Professor Wynne argued that abstract figures on risk like these (numeric probabilities) are not meaningful to the public" (The House of Lords, Third Report, 1999).

Adams (1996) draws from two reports of the British Royal Society, published respectively in 1983 (Risk Assessment*)* and 1993 (Risk: analysis, perception and management), and distinguishes between: objective risk – the sort of thing that experts know about; and perceived risk – the lay person's often very different anticipation of future events. One of the significant differences between the two reports in the attitude of the Royal Society is the emphasis put on perception of risk in the second, to the point where the Society could no longer publish a unanimous opinion in 1993. This evolution may indicate that legislation and regulation could be affected by perceptions of risk more than by objective risk (Adams, 1996).

The divergence between expert calculations and lay perceptions of risk is not always that the perception indicates a higher risk. It has been noted (Sjöberg, 1999) that many lifestyle risks associated with drugs, alcohol and

tobacco are perceived by the consumers to be lower than expert estimates, perhaps due to the comfort or reward obtained. For example, based on the known dose-effect relations between radiation exposure or smoking and the occurrence of a lethal cancer as a result of it, it can be argued that 1 mSv/yr of radiation exposure is roughly equivalent to smoking three packages of cigarettes per year (see, for example, Nifenecker and Huffer, 2001). However, people seem to possess more resistance to subjecting themselves to a radiation of 1 mSv/yr (in addition to the same amount one approximately receives annually from natural resources) than to smoking a few packages of cigarettes per year.

Recognising the inherent differences between objective risks and risk perception, as Sjöberg (1999a) points out, the debate about risk policy is just a special case of the debate about democracy. Do we really want a system of social decision making for the case of risks? Do we want an elite of experts and researchers to have a much larger influence than they have today, perhaps even to make the final decisions without any influence from the public or media exposure?

Tolerability of risk

Industry and regulators have generally observed that at times an individual would tolerate a risk even if his perception of that risk exceeded a regulatory limit. This opened a debate about the choice of tolerated level versus objective assessment of risk, as a basis for establishing regulations. Adams (1996) discussed objective assessment and perceptual expressions of risk and identified the change of opinion about tolerability in the Royal Society reports. The recent work by Simmons (1999) has highlighted the basis to the debate.

It would appear that scientists could calculate objective risks from probabilities for known hazards, and regulations on that basis could be developed. However it was recognised that some communities exhibit a higher tolerance to a perceived risk (TOR), and therefore regulators should consider both public TOR and scientific estimates. However, Simmons (1999) challenges the underlying concept of TOR in that the individual, whilst tolerating a risk, may not have been sufficiently unencumbered to make such a judgement. For TOR to be a valid concept in the assessment or anticipation of a public acceptance of a risk, the risk would need to be discrete, in the future and voluntary. The necessity for the acceptance of a risk being on a voluntary basis is presented by Wynne (1997). It is recognised that the concept of the tolerability of risk is useful in this context.

The concept that the public may have a free standing judgement as to what level of risk is within its tolerance, or that a specific risk is worth taking, is countered by the observation that the "willingness" that is central to the TOR hypothesis was frequently found to be based on habituation, resignation and even fatalism (Simmons, 1999). In the case of apparent tolerability, some respondents may not have been free to act. They may, for example, be employees of the emitting factory or have their equity stranded in nearby family homes and lack the resources and skills to enable them to relocate. This is illustrated by the observation that people living near a factory that emits noxious fumes were indicating that they would tolerate emissions at that level, irrespective of the regulations or attendant risk.

The expressions of risk and probability illustrate that the public are unlikely to comprehend a mathematical expression of the issue but are often asked to judge an issue of risk based on what at best could be a perception. For example, The House of Lords Third Report (1999) states that: "The current Guidance on Requirements for Authorisation contains only one numerical standard for long-term safety: the target that the risk that an individual human being will suffer a serious health effect (fatal or genetic) from any releases of radioactive material from a sealed repository should be less than one in a million (10^{-6}) per year". This would equate to an added exposure to an individual of 0.02 mSv/yr against a background of say 5 mSv/yr (or 10 mSv/yr in a high radon area). In this context, a reliance on apparent tolerability of risk by regulators and industry would need to be closely assessed to discover if the respondents were fully informed, able to understand and free to act.

On the other hand, in cases where expert opinion, based on the scientific assessment, expressed a lower probability to a risk than the public's perceived value of the same risk, industry believed that the regulations should reflect the lower value. This issue is hotly debated and the apparent divergence between the scientific assessment and the lay perception has become an issue for regulators. In some fields scientists claim an effectiveness of risk management and a valid comparative ranking based on their (usually lower) estimates (after Ives, 1996) but the public bases its concern on a more subjective assessment of the same risk. The issue is further complicated by the lack of public confidence in a single regulatory authority and more generally a lack of trust in experts (after Sjöberg, 1999).

Public acceptance of the technical approach

As public concerns regarding nuclear power gained prominence in the 1970s, investigators tried to establish general principles of public risk

acceptability, usually based on mortality statistics and the *de minimis* risk principle. This approach argues that if a risk can be lowered to less than one additional fatality per million citizens then the risk is essentially zero.

The problem is that, while the Probabilistic Safety Assessment (PSA), also known as the Probabilistic Risk Assessment (PRA), results are generally accepted by experts in the field, they have been found to be incomprehensible to the public due to the mathematical expressions of risk used and to the extremely long time horizon involved. However, these two characteristics (i.e. use of mathematical expressions to convey risks associated with events with low probability but high consequence, and the very long time dimension) are inherent to any discussion of risk in the nuclear energy context.

Ultimately, the reliance on the technical approach to risk has been generally unsuccessful. Thus, there has been a need to develop a greater understanding of how the public perceives risk so that more effective decision making and communication processes with the public can be defined. Indeed, over the past three decades, social scientists have studied the ways in which average citizens perceive risks, and have shown clearly that the public tends to view risks differently than "experts" (i.e. the scientific and policy-making communities) view them (USNRC, 1989; Slovic, 1990).

A study by the International Nuclear Societies Council (INSC, 1998) stated that the promise of minimal risk has been implemented by establishing regulations for radioactive emissions that are so low that they are routinely exceeded by other human activities that have no relationship to the use of nuclear power (coal-burning power stations, buildings made of granite rock, flying in jet aircraft), and by adopting operating practices that keep actual operating emissions to about one percent of these already conservative limits.

In the specific case of waste management, according to the same study, following the *de minimis* risk principle has led the industry to spend many billions of dollars to refine the ability to predict the risk to future generations of humanity tens of thousands of years from now, a time frame not even remotely approached by environmental protection measures in other industries. However, the attempt to respond to public concern and opposition in this manner has served primarily to make nuclear power more expensive; it has generally failed to achieve the desired widespread public acceptance.

"The research on the public perception of risk strongly suggests … that no amount of technical proof of safety, or communication of that proof, will suffice to alter public opinion unless other conditions are met first. Unless the immense barriers to communication posed by the risk perception factors are

first overcome or removed, the information will not be received or processed by its intended audience in a manner that lowers the perception of the risk." (INSC, 1998).

From quantitative to qualitative assessment of risk

In the light of this public resistance to the technical approach to defining and communicating risks, research began to focus on the disparity between the quantitative articulation of risks and the more qualitative public perception of those risks. In the 1980s, several groups developed models that incorporated the value systems of individuals, peer groups, and even whole societies into risk communication theories (Vlek, 1981; Douglas, 1986; Slovic, 1987) resulting in broad agreement that risks are viewed according to their perceived threat to familiar social relationships and practices, and not simply by numbers alone.

The psychometric paradigm (Slovic, 1987) describes risk from a psychological perspective, drawing on various characteristics or dimensions which may be important in influencing risk perceptions. Douglas (1982) first described the cultural theory of risk in which individuals can be allocated into cultural groups based on shared values and beliefs. Psychometric research identified several factors which appeared to influence public judgements of risks. Such factors include: involuntary versus voluntary nature of the risk; reversibility or irreversibility; the concentration of equal overall harm in a single catastrophic event rather than its dispersion in many smaller ones; immediate versus delayed harm; whether anonymous or known victims were involved; familiarity of the risk or the process involved; whether there was uncertainty and disagreement about the risk; and how equitable or not was the social distribution of the risk.

Whereas the psychometric paradigm holds that risk itself is deterministic in generating perceptions, the cultural theory holds that the characteristics of the perceiver – rather than the risk itself – are central to an understanding of risk perception. Kasperson (1988) developed the social amplification of risk theory, which suggests a way to integrate the aforementioned frameworks into a comprehensive accounting of the social, cultural and individual characteristics, which tend to magnify or amplify one risk over another (Powell, 1996).

Slovic, whose research on public perceptions of risks over two decades has done much to define the field, has identified a large number of qualitative and value attributes of risks that affect how the public perceives different risks. Slovic defines a "risk space" with two main dimensions. On one axis, risks are ranked from "known" to "unknown". On this dimension are factors such as

whether consumers are familiar with a risk or whether it is novel; whether it is observable by consumers, well known to science, and the like. On the other axis, risks are ranked from "dreaded" to "not dreaded". Captured within this dimension are factors including whether a risk is voluntarily assumed or involuntary; whether individuals can control their own risk, whether it is equitably distributed; whether it has potential for catastrophic consequences; and other attributes (Slovic, 1987).

Slovic's work shows that the farther a risk falls toward the "dreaded end" of that axis, the higher the perceived risk, and the more people want to see the risk reduced, including by regulation. For example, according to Slovic's surveys, radiation from nuclear power plants fall high on the "dreaded risk" axis (Groth, 1998). As Slovic himself says, while these public perceptions of risk may not exactly match experts' narrower, quantitative definitions, the public's perceptions are in fact quite rational; they are merely wider, more qualitative and complex than experts' perceptions of risks, and they incorporate legitimate value-laden considerations that are valid dimensions of risks (Slovic, 1990; Groth, 1998).

Sandman has coined the term "outrage" to encompass many of the qualitative dimensions of risks documented by Slovic and others (Sandman, 1987; Slovic, 1987). In Sandman's terms, "hazard" is the quantitative, measurable aspect of a risk – how likely it is to kill you – while "outrage" is all the attributes of a risk that determine how likely it is to worry you or make you angry. Sandman notes that the public generally pays too little attention to the hazard side of risks, and experts usually completely ignore the outrage side. These are two very different starting points and, not surprisingly, experts and the public often rank the relative importance of various risks very differently.

Scientists, in general, define risks in the language and procedures of science itself. They consider the nature of the harm that may occur, the probability that it will occur, and the number of people who may be affected (Groth, 1991). Most citizens, in contrast, seem less aware of probabilities and the size of a risk, and much more concerned with broader, qualitative attributes, such as whether the risk is: voluntarily assumed; controllable by the individual; necessary and unavoidable; familiar or exotic; natural or technological in origin. They are sensitive to the existence of safer alternatives and to the benefits, if any, associated with a given risk. Sandman also observes that process issues affect outrage. If the public feels its legitimate concerns are not being addressed by the risk-management process, the outrage level – and the intensity of public concern with the risk – will be greater than when the public feels listened to (Sandman, 1987; Powell, 1996).

Technical probabilistic assessments of risk evaluate two criteria: the extent and the probability of damage. The psychometric paradigm research has uncovered more than two dozen criteria which enter into the intuitive estimation of risk and aid in understanding behavioural and affective attitudes toward risky activities or objects, including acceptance or rejection. It allows to grasp what is important about a risk for a specific section of the public, to understand better why public perception differs from that of the experts, and, in the best of cases, how that gap may be reduced.

These intuitive, or implicit, dimensions of risk perception can be grouped into broad classes. The least acceptable risks are those perceived to be uncontrollable, catastrophic, fatal, inequitable, involuntary, not easily reduced, and increasing. In this cluster of descriptors we also find perceived threat to future generations, to children, or directly to oneself. Such risks may also be labelled "dread", that is they inspire strong affective reactions of terror and are difficult to discuss in a detached manner. A second cluster that is helpful in explaining acceptability points to the familiarity of risks; the least acceptable risks are not directly observable, unknown to those exposed, have delayed effects, are recent in popular history or are unknown to science.

Aspects of risk management and communication with the public have also been shown to be important in lay evaluations of risk. Institutional credibility, for example, or the possibility of citizen control and oversight, are important factors in determining public acceptance (Poumadère and Mays, 1995). According to Covello (1992a, 1983), while psychological research has identified 47 known factors that influence the perception of risk (see above), one of the most important factor is trust in the controlling authority.

The actual risk does not change, but the perception can; and in the domain of public policy, perception is reality (Covello, 1988; USNRC, 1989). People do judge risk according to their perception of its controlling agents. If these controlling agents have a track record of secrecy, or they dominate supposedly independent regulatory bodies and the public policy process, then people magnify the perceived risks (Hamstra, 1992; Covello, 1992b; Powell, 1996).

Main factors affecting risk perception and acceptance

The extensive research in the field of qualitative assessment of risk perception has identified a number of key factors affecting public perception of risk and thereby public acceptance of a given level of risk. Key factors relevant in the field of nuclear energy are briefly reviewed below.

Trust

The public acceptance of risk has been shown to be affected by the level of trust that the public has in the controlling authority responsible for setting up regulations, norms and standards and ensuring that they are respected by operators and other stakeholders. In research by Duncan (2001) it has been shown that the public has more trust in composite bodies incorporating a broad range of disciplines including health, environment, communications, science, engineering, sociology and geography. When a risk is local and/or associated with siting of an industrial facility, the acceptance by the local community of the future risk generally is facilitated if a circle of competent locally-based experts is readily available to the interested and affected parties.

Voluntary versus involuntary

As indicated above, there is a distinction between the perceived value of a risk depending upon whether it is voluntary or involuntary (Wynne, 1997). The imposition of a decision, or the taking away of individual or local control, are huge multipliers of perceived risk, each increasing the perception of adverse risk about one thousand-fold. When the policy-making process is such that the public potentially affected by the risk is not adequately involved in the decision, the risk perception is likely to be amplified to a point that prevent furthers communication about the actual risks and benefits of a given project.

Control

People are more concerned about risks not under personal control, such as pesticides on food or risks associated with industrial activities, e.g. nuclear energy, than about those under personal control such as driving a car or smoking cigarettes (Covello, 1994). In this regard, the communication and decision-making processes are essential. Providing the stakeholders with enough information and involvement in the choice between alternative options is a means to enhance their control on the risk and thereby their confidence in its legitimacy.

Benefit/Reward

The acceptability of any risk is often enhanced if it is offset, at least partly, by a reward (Duncan, 1999). For example, motorcycling is about 16 times more dangerous than driving a car; but a motorcyclist will tell you that

the pleasure of wind in the hair and a powerful engine between the thighs is worth the risk. Smoking, which can both soothe and stimulate, entails just the same sort of risk-for-pleasure trade (The Economist, 1997). The challenge for governments and the industry regarding risks associated with industrial facilities, such as nuclear power plants, is to provide the public with credible information on the benefits, e.g. affordable, secure electricity supply, associated with the risks, e.g. effects of radioactive emissions and waste.

Understanding

People are more concerned about poorly understood activities, such as chemical or nuclear energy facilities, than about those that are well understood, such as household accidents or slipping on ice (Covello, 1994). The fact that perceived risks for nuclear energy, including radioactive waste management, are usually greater than the technical expressions arising from an objective assessment of those risks, is thought to be partly attributable to the unknown nature of those risks.

Surveys and analyses of social views about nuclear energy show that the public perception of risks arising from the nuclear energy sector is greater than the objective risk if the cause of the hazard is associated with radiation (Sjöberg, 1999a). Studies in Korea have shown that, both nationally and locally, people having a college education are about 1.2 times more likley to accept nuclear energy than persons having a middle school education (Choi, 2000).

Gender

It may be relevant for policy makers to realise that differences exist between males and females in their perception of risks, in particular regarding those attached to nuclear energy, and that differences in culture, history and continent of origin may be of relevance, although to a lesser extent. Most research in this field demonstrates an empirical association between females and a higher level of risk aversion. The gender effect could be in some part genetic, mimetic or culturally based but it is real and needs to be taken into account in assessing public response to health and environmental issues.

Flynn (1994) and his co-authors looked at the association of gender and race with the perception of environmental health risks, and comment that dozens of studies have documented the differences between risk perceptions of men and women. Their work is based on “white” and “non-white” males and

females in the United States and state that “Men tend to judge risks as smaller and less problematic than do women”.

A recent study carried out in Korea has shown that: “Women perceive risks of nuclear energy to be more existent and benefits to be less than men do. According to the judgement model, this difference shows that a man has about 1.3 times higher tendency of accepting nuclear energy nationally than a woman. And it shows a man has about 1.3 times higher tendency of accepting nuclear energy locally than a woman” (Choi, 2000).

Burger and his co-authors (1998) considered gender differences in recreational, environmental and future land use particularly in respect of DOE’s Savannah River Site. They identified significant gender differences in attitudes in 5 out of 11 issues investigated and in each case the female concern was higher than the males. These issues were ozone depletion, dumping trash in the ocean, high-voltage power lines, radon in houses and pesticides, all of which could have health and environmental effects. Women were more inclined to spend federal funds to reduce the number of high-voltage power lines, preserve rain forests, clean up drinking water, remove lead from drinking water, and solve the ozone problem. It appears from those data that women rank the severity of problems higher than do men and are more willing to have the government pay to solve them.

Catastrophic potential

People are more concerned about fatalities and injuries that are grouped in time and space, such as aeroplane crashes, than about fatalities and injuries that are scattered or random in time and space, such as automobile accidents (Covello, 1994). This is a matter of importance for nuclear energy, since nuclear accidents may involve, as has been demonstrated by Chernobyl, a significant number of casualties at once. Also, the shadow of nuclear weapon impacts remain in public minds when hazards from civil nuclear energy applications are referred to, irrespective of the absence of link between the two types of risks.

Perception of risks from nuclear energy

Regarding nuclear energy, the absence of cognition of the hazard is especially relevant. Beck (1992) asks “What would happen if radiation itched?”. He concludes that “in that case, nuclear policy, as well as dealing with modern mega-hazards in general, would confront a completely changed situation: the objects being disputed and negotiated would be culturally perceptible”.

Democratic control of risk is only possible, he insists, if we can gain "the competence to make our own judgement through a culturally created perception of hazard" (cited by Adams, 1996).

Also, specific characteristics of nuclear energy are leading to public perception of associated risks. In particular, the way nuclear energy projects are implemented makes it difficult for civil society to feel associated with its benefits, and thereby to accept its risks. Nuclear energy projects give an image of benefiting only companies, utilities, and their shareholders, while society, especially local population, is subjected to the burdens and risks associated with the construction and operation of industrial facilities.

The public perception of risks from nuclear energy differs markedly from the scientific assessment of those risks and even from the actual experience reflected in statistical data on damages, morbidity or mortality resulting from nuclear energy activities. Studies have shown that the general public evaluates risks not by the standard scientific computation of probability times consequence, but through a series of subjective criteria.

The criteria that affect public perception of risk in the field of nuclear energy include:

- Complexity of a technology that is not well understood by ordinary people and requires specialists for its operation.
- Centralised rather than local control of the projects so that affected people cannot participate in operating decisions.
- Potential for a high consequence accident as a result of a single failure, even if it is recognised that the probability of occurrence is very low.
- No clear need, at least in most OECD countries where security of electricity supply is of no immediate concern, and no perceptible benefit.
- Invisibility of the risk source (radioactivity).

Table 3.1. Doses from various radiation sources

Source	Dose (μSv/year)
Earth's crust (Cornwall, UK)	7000
Earth's crust (Sydney, Australia)	160-900
Outer space (sea level)	260
Medical X-ray	200
Living in stone, concrete, or brick building	70
Airline flights (per 1,000 miles flown)	10
Computer terminal	1
Coal-fired power plant (within 50 miles)	0.3
Nuclear power plant (within 50 miles)	0.09
Smoke detector	0.08

Sources: Nuclear Energy Institute and World Nuclear Association.

The loose correlation between risks and public perception of risks in the field of nuclear energy is well illustrated by exposures to radiation and how people feel about it. Table 3.1 provides radiation doses resulting from natural background in various locations as well as from a number of human activities such as medical X-ray and nuclear energy. It shows that exposures to radiation resulting from natural background vary within a wide range but are in all cases higher than exposures resulting from artificial radioactivity. Also, exposures associated with routine activities such as using a computer or flying overseas largely exceed exposures from nuclear power plants. In other terms, the risk from activities generally perceived by the public as non-risky far outweighs the objective risk of living close to a nuclear power plant, generally held to be risky by the public. While, as stressed above, risk perception is an important dimension for social acceptance of risk, disseminating factual information on comparative risks to the public may be relevant to provide civil society with a robust background on which to base its view about nuclear energy.

The INSC study of 1998 summarised key issues about public perception of risks associated with nuclear energy as follows: "The public concern about nuclear power is, in most countries, especially high in communities that have no previous experience with nuclear energy but might become sites for a future generating station or waste disposal facility. This can be viewed in terms of the community making a decision based on its perception of the risks and its perception of the benefits. The risk may be perceived to be very high because the facility is imposed on the community (involuntary), because the matter was not well understood, because it is perceived that a failure of the reactor or disposal

system could result in disastrous consequences, because the technology is complex and requires specialists whose human values are unknown, and because decisions were made centrally rather than by local people. The main benefit from the proper operation of the reactor or waste management facility is perceived to be reflected in corporate profits and perhaps lower electricity prices for all electricity users, with no special benefit to the community near which the proposed facility is located. It does not generally matter that the facts are different. The community can make decisions only on its perception of what is true. If the perceived benefits do not outweigh the perceived risks, the decision will be negative." (INSC, 1998).

Knowledge, or rather the absence of it, and lack of perceived benefits are important factors for public perception of nuclear energy risks. Risks from familiar things, which people feel they understand, control, and make decisions about themselves, and from which they believe they derive a direct benefit, are perceived by to be relatively low by the public. This is so even when there is common knowledge that the technology or activity results in a large number of deaths. For example, although it is demonstrated and known that driving cars is causing daily accidents and fatalities, the public seems to perceive automobiles as much less risky than nuclear energy.

Recent research shows that perceptions of risk form one part of the process of acceptance of a public proposal while the potential benefits of the assumed risk form another. The outcome of a complex calculus taking into account trade-off between perceived risks and perceived benefit is the ultimate driver of public views. A study carried out in Korea has shown that these two variables, perceived risk and perceived benefit, can effectively bound the envelope of acceptance of nuclear energy. The study concluded that: "The level of perceived risk and benefit is a key factor for determining the level of national and local acceptance of nuclear energy. Perceived benefit is more influential on national acceptance than perceived risk. However, perceived risk is more influential on local acceptance than perceived benefit" (Choi, 2000).

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4. PUBLIC INVOLVEMENT IN NUCLEAR DECISION MAKING

Introduction

This chapter assesses how public involvement in decision making regarding nuclear energy issues can be facilitated. It covers involvement of stakeholders, i.e. people with special interest in a given project, and general public involvement. Policy on complex technical nuclear issues has long been determined by the idea that a key element in public acceptance was the provision of adequate information on the issues. While it still is true that provision of adequate information is essential, it no longer is seen as sufficient in itself. Today the need for greater direct public participation in scientific and technical decision making is recognised. The chapter analyses whether and by what means the public can obtain more decision-making authority in nuclear energy issues through direct involvement.

First, the chapter elaborates on why the public ought to be involved in making decisions regarding nuclear energy issues, and how, through democratic engagement in science communication, public confidence could be renewed. Then, it provides examples of current innovations in organising public participation in nuclear decision making, and distinguishes between deliberative and inclusive public involvement, as well as between stakeholder and general public involvement. A variety of topics regarding the relation between the general public opinion and planning, such as questions regarding national security, the role of the Internet, and geographical aspects of nuclear energy decision making are addressed. The process and acceptance criteria for public involvement in decision making is described. Finally, the chapter summarises where we currently stand on the public participation ladder, as well as whether and to what extent we can go beyond the present level of rather restricted participation.

Rationale behind public involvement in nuclear energy decision making

From education and information to public participation

Governmental policy on scientific and technical issues was until recently guided by the belief that education and information would increase the public understanding of science (for the United Kingdom, see, for example, Royal Society, 1985). However true this belief might be, this policy also assumed that greater public acceptance of scientific research and technological development would come with greater understanding of the science involved. The latter assumption, however, might be erroneous, especially in the face of two observations:

- A strong research-based challenge exists to the traditional view that the public is ignorant and irrational, when it comes to scientific and technological matters, and thus needs to be educated.
- A growing public scepticism and distrust of science has been emerging.

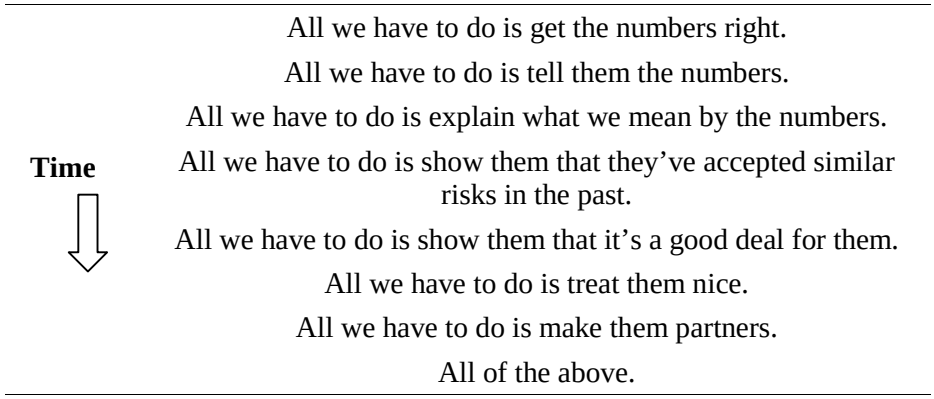
Upon gradually realising and accepting these two considerations, the scientific community recognises more and more the need for greater public participation in scientific and technical decision making. Public involvement may be achieved at different levels. At the very lowest level, the public may be the recipient of information from an organisation. At a higher level, the public may be given the opportunity to express their views via questionnaires, focus groups or other consultation exercises. At an even higher level, involvement may mean that the public possesses some degree of decision-making authority. Although involvement at this higher level is still relatively rare, there has been a general trend towards more iterative science and technology decision making, characterised by dialogue and two-way information exchange. This can be illustrated with reference to the evolution of risk communication, a particularly salient issue in the domain of nuclear energy.

From "deficit model" to "democratic engagement model" in communication about science

Historically, the conception of risk communication has transformed "from an emphasis on public misperceptions of risk, which tended to treat all deviations from expert estimates as products of ignorance or stupidity, via empirical investigation of what actually causes concern and why, to approaches which promote risk communication as a two-way process in which both

"expert" and "lay" perspectives should inform each other" (Bennett, 1998). Fischhoff (1995) traces the evolutionary process of risk communication in the way listed in Figure 4.1. Originally, risk communicators wanted simply to convey the correct numbers. This approach, however, proved dismally inadequate, as expressed in "so risk communication practices evolved … until the professional risk community came to the conclusion that risk communication means to make the public a partner in the mutual attempt to manage risks" (Renn, 1998).

Figure 4.1. Evolution and prescriptions for communicating risks to the public



Source: Fischhoff, 1995.

On this recent dialogical understanding, public involvement in science and technology decision making should be underpinned by the recognition that the ordinary public can make a serious contribution to decisions. Recent innovations in public involvement have supported this view, as demonstrated in practice in a number of cases, notably in Europe. Indeed, some European countries have been less guilty of underestimating the decision-making capacities of their citizens than other countries. In Germany, for example, *planning cells* have been established to increase public involvement in decision making. These planning cells are similar to citizens' juries or panels, but may involve up to 500 people, divided into groups of about 25. They are often used to achieve public judgement on complex technical issues. Concrete examples of the use of planning cells include *Future Energy Policies of West Germany* (1985), *Potential Use of Videophones* (1991) and *Energy Supply for Juchen Nord* (1993). In Switzerland, similar planning cells have been used for the *Siting of Landfill Sites in Argua* (1992). As Wynne contends, "it has been found time and again that, even when not technically literate in the relevant arena, lay publics are typically adept at placing the specific issues in a measured context

that is relevant to them, and at posing highly germane questions which experts have often ignored" (Wynne, 2000).

Renewing confidence in science

The UK House of Lords Select Committee Report *Science and Society* (House of Lords, 2000) was initiated on the basis of a previous study conducted in 1998-99 on the Management of Nuclear Waste (House of Lords, 1999). Drawing on several research studies, this influential report warns of "an apparent crisis of trust" and "increasing scepticism about the pronouncements of scientists on science-related policy issues of all types". The report concluded that the UK "must change institutional terms of reference and procedures to open them up to more substantial influence and effective inputs from diverse groups".

Increased public involvement in scientific and technical problem solving has been advocated by many, as a way of renewing a relationship of trust between scientists and the lay public. Renn (1998) argues that most scientific debates operate on three levels:

- factual evidence;
- institutional performance, expertise and experience; and
- conflicts about world views and value systems.

At each level, public involvement may be desirable. On the first level, evidence may be biased by framing effects or dogged by ambiguities or uncertainties that need effective communication. On the second level, which is concerned specifically with institutional competence, trust can be sub-structured into five components (Renn and Levine, 1991):

- perceived competence (degree of technical expertise);
- objectivity (lack of biases in information as perceived by others);
- fairness (acknowledgement and adequate representation of all relevant points of view);
- consistency (predictability of arguments and behaviour based on past experience and previous communication efforts); and
- faith (perception of good will in composing information).

For example, there may be cause to reaffirm the independence of an organisation from powerful vested interests to convince the public of its objectivity. Alternatively, the focus of debate may raise equity issues, such as the distribution of risks and benefits. In this case, the organisation may be evaluated according to the trust factor of fairness. All components of institutional trust are both demonstrable and communicable to the public in a context of institutional openness and transparency.

On the third level, decision making necessitates a more fundamental societal consensus on issues underlying scientific and technological debate. As we have witnessed with genetically modified (GM) foods, conflict at this level may be defined along different social values and cultural lifestyles. Perhaps the most persuasive argument for increased public involvement is that value judgements are made at all three levels of scientific and technological decision making (Rowe and Frewer, 2000).

Examples of current innovation in organising public participation

Deliberative and inclusive public involvement

Two key features of recent methods of public involvement are that they are *deliberative* and *inclusive*. *Deliberation* means that information and different viewpoints are reflected upon and carefully considered. Exposure to a deliberative process enables and encourages participants to re-evaluate their own positions and adopt an enlarged viewpoint. The principle of *inclusivity* ensures that processes of public involvement aim to include participation by a broad range of individuals and groups from different standpoints in society. A particular focus on widening participation to previously excluded individuals and groups such as women, the young and ethnic minorities is evident in many new methods of public involvement.

Stakeholder involvement

There are various innovative methods for bringing together stakeholders, i.e. different groups concerned with a given issue. Most of these methods can be structured and may be facilitated. They may be oriented to a specific task or to a continuous mode of engagement. *Mediation groups* are usually initiated in order that parties in conflict over an issue may be brought together to try to work things out. *Consensus-building* is an approach designed to confront the issues and not the people. It usually involves representatives of different interests

meeting together to seek to achieve consensus over an issue. *Future search conferences* have been developed to enable a wide range of stakeholders to create a shared vision of the future for a community or organisation. Such conferences may involve methods such as role-play, discussion based on different scenarios, or action-planning.

In contrast to approaches that seek consensus, facilitated *stakeholder* or *peer dialogues* may be organised with the intention of inviting interested groups into discussions based on principles of openness, transparency and equal respect. The institution has no obligation to act on the outcome of the dialogue. It must only provide the information required for the discussions. *Multi-stakeholder workshops* have been developed as a means for increasing trust and understanding between different stakeholders associated with a particular hazard domain (e.g. related to food, health or environmental risk). The technique involves bringing key stakeholders together to work through a hypothetical, but realistic, scenario describing some risk situation. Stakeholders' understanding of the situation and their expectations about how regulatory authorities and other stakeholders should act are elicited in separate syndicate groups. At a later stage, these are open to more general discussion in a plenary session (see French and Maule, 1999).

Two interesting examples of consensus building are found in the United Kingdom and Canada. In the county of Hampshire, UK, consensus building has been employed successfully by local government to confront a crisis in waste management. "The county council had proposed to replace four old incinerators, which did not meet EU standards, with one large waste-to-energy incinerator at Portsmouth. Local opposition forced the abandonment of the proposal and the county turned to consensus-building" (Stewart, 1996). *Round tables* have been developed in Canada at national, provincial and municipal level to bring stakeholders together on a continuing basis. They are designed to analyse problems from a cross-disciplinary and cross-jurisdictional perspective and are a method of bringing together traditionally adversarial groups. Members of local round tables, generally between 16 and 24, may be nominated by an institution.

General public involvement

The *survey* method is not a new (or deliberative) method of public involvement. Still, it is widely used. It is a quantitative tool which is underpinned by the notion that a large number of responses means that the outcome is representative of the constituency targeted for consultation. Perceptions, opinions, attitudes and individual preferences may be collected for

statistical analysis by such survey methods. Responses are elicited by the use of a questionnaire, which may be administered face to face, by telephone or by post. The design of the questionnaire is of paramount importance, since the quality of the survey responses is linked directly to the quality of the questions. Furthermore, because surveys are designed to be representative, their statistical significance is undermined if the response rate is low.

An example of an opinion poll in which the number of questionnaire responses was large enough to be of statistical significance was the opinion poll conducted in October and November 1998 on behalf of the EC Directorate-General XI entitled *Environment, Nuclear Safety and Civil Protection*. Under Eurobarometer 50.0, the poll was designed to report on Europeans' perception of issues associated with radioactive waste. In each European country, questions were put to a representative sample of the national population aged fifteen and over. In all, 16 155 people were questioned (INRA, 1999).

A new innovation that combines the advantages of the survey method with deliberation is the *deliberative opinion poll*. In a deliberative poll, several hundred people may come together to debate an issue. They are usually able to question key actors. Like the survey, the opinion poll is representative of the population because of its large number of participants. The group is usually polled both before and after deliberation. Deliberative opinion polls, however, are expensive, and may easily cost around € 200 000.

Focus group polls lie somewhere in between the immediate response elicited from a survey and the considered response characteristic of deliberative mechanisms of public involvement. Focus group polls are a well-established, qualitative research tool developed to elicit responses around a complex issue that may need some degree of informative input or discussion. Discussions in small groups of between 8-10 selected participants are designed to focus on a particular issue. The contents of the discussions are analysed to obtain insight into shared understandings, attitudes and values. The purpose of a focus group poll is to offer understanding into how participants perceive and talk about issues in the context of their everyday lives. Participants are usually offered an incentive to take part in a focus group poll, e.g. in the form of a small sum of money. Typical costs of these polls are around € 1000-2000.

Citizens' juries or *panels* are deliberative forums (Smith and Wales, 2000). In common with a legal jury, "the citizens" jury assumes that a small group of ordinary people, without special training, is willing and able to take important decisions in the public interest" (Coote & Mattinson, 1997). Panel members are recruited from the general population by stratified random sampling, and are considered typical of ordinary citizens within the affected

constituency. Over a number of days (usually 3-4), "witnesses" present information and views around an issue to participants. With trained moderators ensuring fair proceedings, panel members are given the opportunity to cross-examine the witnesses. Following a process of deliberation, the jury produces a decision or a set of recommendations in the form of a citizen's report. Participants are usually compensated for their time by being paid a small amount of money. Typical costs of citizens' juries are € 15 000-30 000.

Issue forums have been developed in the United States as a means of improving the quality of public judgement. Like citizens' juries, this method of public involvement is characterised by information and deliberation. Issue forums can encompass community-wide town meetings, or rather small study circles of between 5 and 20 participants. They may be one-off events or meet several times to work through the issue at hand. Trained moderators may guide the various discussions. For example, there has been an issue forum that covered *Energy Options: Finding a Solution to the Power Predicament* (Stewart, 1996).

The *consensus conference* is a particular form of public inquiry in which 10-20 participants assess a socially controversial topic of science and technology. The consensus conference emerged in the United States in the 70s to assess new and frequently expensive medical treatments. Consensus conferences have now been developed by a number of countries around the world and can deal with a large variety of topics. The idea underpinning a consensus conference is to broaden the discussion of contentious or potentially contentious areas of science and technology by including members of the general public. In common with the citizens' jury, participants have no special knowledge of, or vested interest in, the issue under discussion, but pursue the topic from the point of view of the ordinary citizen (Joss and Durant, 1995). Lay participants ask questions and put their concerns to a panel of experts, assess the experts' responses and then deliberate amongst themselves. The outcome is a consensus statement that is made public in the form of a written report at the end of the conference.

To give an example of a consensus conference, in 1999 such a conference was organised by the UK Centre for Economic and Environmental Development (UKCEED) to discuss the future management of radioactive waste. The concerns of conference participants reflected a number of themes, related to the need to (see Parliamentary Office of Science and Technology, 2001):

- ensure openness, transparency and the inclusion of lay perspectives in decision making;

- establish strong, independent and effective regulatory bodies that can command public trust;
- ensure that managing radioactive waste is guided by precaution, particularly to safeguard future generations; and
- consider radioactive waste management in the wider context of energy policy more generally.

Finally, another option for general public involvement in decision making is the establishment of a *standing panel*. In 1998, the Cabinet Office established the UK's first national standing panel, called the People's Panel. With 5 000 participants the People's Panel may be seen as representative according to specific demographic indicators such as age, gender and region. Standing panels provide a pool of participants, who may be used to identify representative groups of service users, to consult on various issues, to track how and why views are changing, and to conduct a range of surveys.

Public and planning

National security and national public opinion

Energy provision is an issue of national importance and one that has close links to various aspects of national security. As a result of this, the degree to which the general public is provided with the opportunity to become actively involved in decisions regarding national energy policy is traditionally rather limited. Partly out of national security considerations, planning for energy provision is largely considered to be a task for central government and utilities. Public involvement in the energy planning system is therefore often perceived as a *them-and-us* situation, with authoritative decision makers having almost exclusive access to knowledge, expertise and power.

Other participants in the process are usually large organisations or pressure groups with certain vested interests, as opposed to individuals or small community groups with specific ideas on the subject matter under consideration. This can lead to the vocal minority dominating the debate, at the expense of the opinion of the general population. As Healey *et al.* (1988) state "many people who may have equally if not more valid points to make, resist from expressing their concerns, opinions and viewpoints". The picture of the seemingly national public opinion observed is, as a result, often skewed and biased. It is in the interest of all concerned that this biased general opinion is transformed into a more transparent and inclusive view.

The ability of the public to effectively participate in the energy-planning process depends on a variety of circumstances and access to resources. It takes "time, familiarity and confidence with bureaucratic procedures, personal contacts in key places, money for campaigns, private transport in order to attend meetings, etc." to participate in (nuclear) decision-making processes (Parry *et al*., 1992). All these factors play a key role in whether the public can or cannot be involved in the decision process. While this situation may not appear to be encouraging for participatory democracy, evidence from some countries (see, for example, Howard, 1998) suggests that technologies may have a leading role to play in whether and how the public can participate in the everyday running of their communities.

The role of the Internet

The proliferation of the Internet as a communication medium over the last decade has provided many new opportunities to disseminate information to the public in addition to traditional tools such as newspapers, TV and radio. While the degree of use varies between different countries, governments and organisations, the potential for using the Internet and, in particular, the World Wide Web (WWW), within the energy planning field is significant. While it should be recognised that social exclusion in the so-called information society is an important issue, there are many benefits which web-based public participation can bring to the energy-planning process, including easy access to information and highly interactive modes of communication. In the first half of the 1990s, when the WWW was still to a large extent in its infancy, technological enthusiasts were forecasting a bright new future based on *cyber-democracy*. The Internet is central to this vision and could, according to its supporters "generate a new public sphere supporting interaction, debate, new forms of democracy and *cyber cultures*, which feed back to support a renaissance in the social and cultural life of cities" (Graham, 1996). A key development in recent years has been the integration of two technologies in particular, the Internet and Geographical Information Systems (GIS).

Many environmental decision-making problems have at their core a significant spatial element, not least decisions concerning nuclear energy, such as reactor siting, fuel transportation and the location of waste disposal repositories, which often can be best represented in map-form using a GIS. A GIS is a computerised mapping and database system capable of holding, displaying, manipulating and analysing spatially referenced data. They are widely used in the field of environmental planning, as a decision support tool (Stillwell *et al*., 1999). The GIS and WWW technologies can be used together to provide the general public with a powerful mechanism for becoming more

involved in environmental decision problems through the medium of electronic maps. By providing full access to both spatial and non-spatial data, along with the appropriate tools with which to handle these, the general public may be better able to make informed contributions to the energy debate and the corresponding decision making. This gives the public greater opportunities of engagement at a more equal level with those bodies legally entrusted with decision-making powers at local, regional and national scales. This creates a more "level playing field" for all, and ought to foster a better sense of trust among stakeholders.

This optimism notwithstanding, a number of authors have highlighted a range of problems concerning technical approaches to public involvement, including the four issues described below.

Public access to the Internet and training in its use

Possible increases in participation may be contradicted by the inequalities of public access to the Internet, and unfamiliarity with computers in general. Despite its popularity, many people do not have access to the Internet or computers in general, and so may be disenfranchised by any greater move toward IT-based participation. Research has shown that older people and the economically disadvantaged are particularly under-represented in the group of people having access to computers and Internet (McGrail, 1999). However, it is expected that over the next decade, Internet access will continue to grow, eventually becoming as widely used as other consumer electronics (NOP, 1997 and 1999). Access is also increasingly being made available through open-access points in public places, such as internet cafes, libraries, community centres and council buildings, as well as through schools, universities and businesses (Liff *et al*., 1999). Together, these generate ever-widening opportunities to get on-line.

Public understanding

Further issues surrounding the empowerment of the public, and how it may interpret and use GIS-type tools on the WWW, have been explored in the literature. Monmonier (1996) argues that the public access to GIS technology in opposing siting decisions for controversial facilities can actually put these facilities in a weak position. He also suggests that the public "armed with a GIS, but lacking the savvy to use the systems appropriately, becomes vulnerable to sarcastic attacks from site advocates". Alternatively, it may be argued that providing public access to GIS via the Internet through carefully designed interfaces can enable the public in a positive way, that is, when the mode of

employment is controlled in such a manner as to avoid its inappropriate use. Examples from several communities in the United States have returned encouraging results vis-à-vis all aspects of the decision-making process (Schiffer, 1995).

Institutional difficulties

A further difficulty concerns the willingness of governments, utilities and regulatory bodies to place sensitive information and significant decision-making powers in the hands of the public. This may have been particularly true in the case of the nuclear industry, with its inherent implications for national security (Eiser *et al*., 1995). However, broad public involvement in decision making about nuclear energy, through a referendum for example, did occur in several countries very early on. This is illustrated by the nuclear energy moratorium decided in Austria and the nuclear energy phase-out decided in Sweden.

Social exclusion

GIS has in the past been accused of being an elitist technology, giving more power to those people already possessing it and depriving those, namely the general public, who more often than not lack such direct forms of information access (Pickles, 1995, and Monmonier, 1996). It is nonetheless suggested that Public Participation GIS (PPGIS) could help overcome such criticism by creating a more level playing field on which to conduct public debate.

Despite these several doubts, new forms of participation are beginning to evolve, and experiences from the US and elsewhere suggest that there are many advantages to web-based participation (Howard, 1998). Three properties of public participation via web-based systems seem of outstanding importance, and can be summarised as follows.

Ease of access and ability to participate

A key advantage is that public participation is not restricted by geographical location. Access to the information about the issues being discussed is available from any location that has web-access. The information is also available at any time of the day, thus avoiding the problems associated with holding meetings. The concept of “24/7” access (i.e. 24 hours a day, 7 days a week) opens up opportunities for more people to participate in public consultations (Kingston *et al*., 2000).

Social equality

With a web-based system, the public is at the end of an Internet connection that enables it to make comments and express its views in a relatively anonymous and non-confrontational manner. This can be advantageous in terms of enhancing social equality. Relative anonymity provided by the web in comparison to the traditional method of making a point verbally, in front of a group of relative strangers can be particularly important for some people (Parry *et al*., 1992).

Transparency

If a policy of transparency is to be pursued, the public needs access to all relevant information that is available and that is not considered too sensitive for reasons of national security. Web-based systems can provide quick access to very large amounts of information in a variety of formats and at a variety of levels. At the same time, web-based participatory systems can be transparent in giving general access to on-line consultations as well as feedback.

These issues are illustrated through the range of recent examples of web-based public participation developed across a range of issues and spatial scales in the field of nuclear energy. Findings from this concrete experience indicate that providing access to particular decision-making problems over the WWW could play an increasing role in the way future decisions about nuclear energy will be made.

Some websites run by the nuclear industry and government regulatory bodies are non-interactive and have a policy of "information only". A good example of this is the UK National Radiological Protection Board (NRPB) website (www.nrpb.org.uk). One of the stated policies of this website in its development is that it should be non-interactive (Croft, 2000). Other industry websites go further by inviting public interaction and participation in the decision process. For example, the Canadian Nuclear Safety Commission (CNSC) invites public participation by publicising the details of public hearings, and providing online access to consultation documents (www.nuclearsafety.gc.ca). Public response is invited via e-mail or on paper. The UK Health and Safety Executive (HSE) runs a similar set of web-pages, dedicated to putting consultative documents, discussion documents and consultative letters in the public domain (www.hse.gov.uk/new/index.htm). Transparency of this nature is becoming increasingly popular within the nuclear energy community, with web-pages at the forefront of public information. Two quotes point this out rather well. "As a generality, it is important to encourage

as much open publication as possible of these issues" (Sir Francis Graham Smith, Manchester University, UKCEED, May 1999). "We should all be involved in deciding what happens to it (radioactive waste)" (member of the public, Future Foundations Focus Group, April 2000). These two quotes appeared prominently on the front page of the Nirex website (http://www.nirex.co.uk/), which illustrates the argument very well.

The role of geography in communicating issues to the public via online resources needs to be recognised. Some nuclear industry sites do include information in map-form about the geography of nuclear energy. For example, the ANDRA (French Agence nationale pour la gestion des déchets radioactifs) website has simple maps showing the locations of nuclear facilities (www.andra.fr/home.htm). Other, more experimental, sites go much further and offer access to the public to online GIS. A good example is the use of on-line GIS pioneered by researchers in the UK to allow the public to participate directly in siting decisions. The Centre for Computational Geography's radioactive waste website allows members of the public to interact with digital maps and make their own siting decisions (www.ccg.leeds.ac.uk/atomic and www.ccg.leeds.ac.uk/mce). This is an example of where web-based PPGIS can forward the goals of openness in decision making about nuclear energy.

It is worthwhile pointing out some of the principles of web-based PPGIS and its relation to the role of geographical space in nuclear energy decision making. Web-based PPGIS is in its infancy. While many organisations have shown an interest in implementing such systems within their planning procedures, only a small number has made any steps towards carrying out such a strategy. In light of the recent research into real decision-making problems (see, for example, NCGIA, 1998), a set of PPGIS principles have begun to emerge which could be used as a guide to implementing a web-based PPGIS strategy. An on-line system should (after Carver *et al*., 2001):

- allow the public to explore and experiment with the available data and information sources, and provide the opportunity to formulate different scenarios and solutions to decision problems;
- be understandable by all sectors of the community who wish to be involved, without becoming tied-up in technical jargon;
- provide information and data that is both explicit and bipartisan; and
- foster a high degree of trust and transparency that can be maintained within the public realm to give the process legitimacy and accountability.

One way of addressing the final principle is through maintaining web-based PPGIS and publishing summaries of public inputs, while demonstrating how these have been used to develop policy and make decisions, which themselves are then available for public scrutiny and comment. Such "living systems" may well go a long way in fostering continued participation and wider acceptance of planning decisions.

A series of technical issues also needs to be considered when implementing an on-line PPGIS. These are discussed in great detail in Kingston *et al.* (2000). Results from case studies have shown that spatial scale can have a significant effect on the manner in which the public responds to particular decision problems. In local situations, by far the greater majority of local people are very interested in those decision problems that pertain to their area and thus affect them directly. As spatial scale increases from the local to regional and ultimately to the national scale, fewer and fewer people are interested in the issues, despite the fact that in some situations, for example radioactive waste disposal, the actual decision problem becomes more important and more complex. Only people who are already interested in the problem at the national scale may then appear to participate in the local aspects of a waste disposal problem. This is termed the "inverse-scale" effect (Carver *et al*., 2001). However, as siting or other decisions are made at regional and national scales, the problem and its on-the-ground ramifications return to the local scale, thus generating the same majority level of interest.

Geography and nuclear energy

Geography is important for many decisions regarding energy. For example, the locations of power stations are determined by centres of demand for electricity (cities and industry) and sources of supply and distribution (fuel supplies and proximity to distribution grids). The geography of nuclear energy is particularly important, most notably because of its high public image profile and the effect of nuclear installations on local areas. It is possible to view the social aspects of nuclear energy at three basic levels: national, regional and local.

At a national level, the social arguments for or against nuclear power are closely bound up in national politics, national security and availability of alternative sources of energy. Where traditional forms of energy (oil, gas, coal and hydropower) are limited, the nuclear option seems to be viewed more favourably, and the national interest argument prevails. In this context, France and Japan are good examples. Other countries maintain a strong mix of nuclear and other energy sources, both fossil fuel and renewable. The United Kingdom

is a good example here. At the level of the individual, most people are passive about where their electricity comes from, as long as it is there when they flick the switch. In some other countries, a strong anti-nuclear feeling has developed, leading to conflict. Germany is a good case in point, with the anti-nuclear lobby being closely associated with the strength of Green Party politics, although up to 40% of the population are critical of the government's nuclear opt-out policy (Kocher, 2000). Other countries have simply taken the decision that nuclear energy involves too many uncertainties and have taken decisions to stop building new facilities and close existing ones as they come to the end of their operating life. Sweden is an interesting example here (Sjöberg and Drotz-Sjöberg, 2001).

At the regional level, the picture is less clear, depending on prevailing regional patterns of energy demand, politics, employment and social mix. Evidence of strong regional opinion towards nuclear energy can be seen in the setting-up of "Nuclear Free Zones" (Yakemtchouk, 1997).

At the local level, opinion is extremely polarised. People who are passive about nuclear energy (or even pro-nuclear) at a national scale, may become vociferously anti-nuclear as soon as they are directly affected by a proposed new power station or waste disposal facility in their locality. This is what is generally termed the NIMBY (Not In My Back Yard) syndrome. NIMBY is a typical "knee-jerk" reaction to proposals for new facilities in hitherto undeveloped areas, making it clear to see why geography is so important to the individual as well as the wider economic picture. The risk to the individual associated with nuclear energy is often seen as acceptable at a national scale, when risks are expressed in terms of extremely low probabilities of harmful effects. The risk becomes unacceptable, however, when the individual sees himself as the statistic, by way of living in close proximity to the source of the risk (Damveld, 1999). The NIMBY reaction is further heightened when people realise that the price of their house may be adversely affected through having a nuclear facility as a neighbour (Clarke and Allison, 1999). This is a phenomenon known as "planning blight".

The alternative local view of nuclear energy is very different. In areas with a long history of association with the nuclear industry, local people are often strongly pro-nuclear because of local economic support in terms of jobs, infrastructure and multiplier effects. In some countries, additional economic and civic incentives are offered by central government to local people who "host" nuclear developments. Good examples are France and the United States, where lower taxation and subsidised local civic facilities are offered by way of incentive (Opp, 1986, and Williams *et al*., 1999).

Maps, GIS and spatial decision support systems have a potentially important role to play in addressing the issues of location and space presented by nuclear energy. They may not necessarily provide solutions to the problems of national and local uncertainties, but they can help clarify the issues (MacEachren, 2000). It is perfectly possible to address all of the issues surrounding the nuclear debate in non-spatial terms. Arguments for and against nuclear energy can be made on a national (or global) scale without reference to maps or other forms of spatial data. Opinions are simply expressed as trade-offs between costs and benefits, and the associated risks (environmental, economic and health). Development of nuclear energy, however, inevitably involves spatial decisions about where to build power stations, fuel processing plants, research laboratories and radioactive waste disposal facilities. It is these decisions that affect people most directly and so cause the most concern. By careful use of spatial information and spatial decision support systems (incorporating GIS and other spatial information technologies), these difficulties may be best addressed. Placing these in the public domain, using the Internet, demonstrates both the geographical picture to a concerned population and a desire for transparency and accountability on behalf of the decision-making authorities.

Process and acceptance criteria for public involvement

Evaluation of new methods of public involvement should take into consideration both the added qualitative value that public deliberation may bring to a decision and the potential for increased democratic legitimacy of decisions (Renn *et al*., 1995, and Rowe and Frewer, 2000). Along these lines, Rowe and Frewer (2000) divide their evaluation criteria into *process criteria*, which are related to the effective construction and implementation of a procedure and *acceptance criteria*, which are related to the potential public acceptance of a procedure.

Process criteria include:

- *Resource accessibility:* public participants should have access to the appropriate resources to enable them to successfully fulfill their brief.
- *Task definition:* the nature and scope of the task should be clearly defined.
- *Structured decision making:* the participation exercise should use/provide appropriate mechanisms for structuring and displaying the decision-making process.

- *Cost-effectiveness:* the procedure should in some sense be cost-effective.

Acceptance criteria include:

- *Representativeness:* the public participants should comprise a broadly representative sample of the population of the affected public.
- *Independence:* the participation process should be conducted in an independent, unbiased way.
- *Early involvement:* the public should be involved as early as possible in the process as soon as value judgements become salient.
- *Influence:* the output of the procedure should have a genuine impact on policy.

Generally speaking, if methods of public involvement were measured against these criteria it becomes evident that no single method can attain a perfect "score". For instance, those methods that score high on the "representative" criterion, e.g. public opinion polls, standing panels and multiple focus groups, tend to score lower on the process criteria (excepting cost-effectiveness). There is often a trade-off to be made between the deliberative dimension some methods offer and the representative capacity of others, which deliberative opinion polling tries to remedy rather expensively. This point is significant, in that it underlines the fact that no one method of public involvement may be viewed as a panacea. Methods should be employed with a clear purpose in mind, and invariably a number of different methods may be utilised as part of one decision-making procedure. Evaluation that considers an organisation's decision-making processes as a whole, in the light of criteria such as those offered by Rowe and Frewer, is an important area for future research.

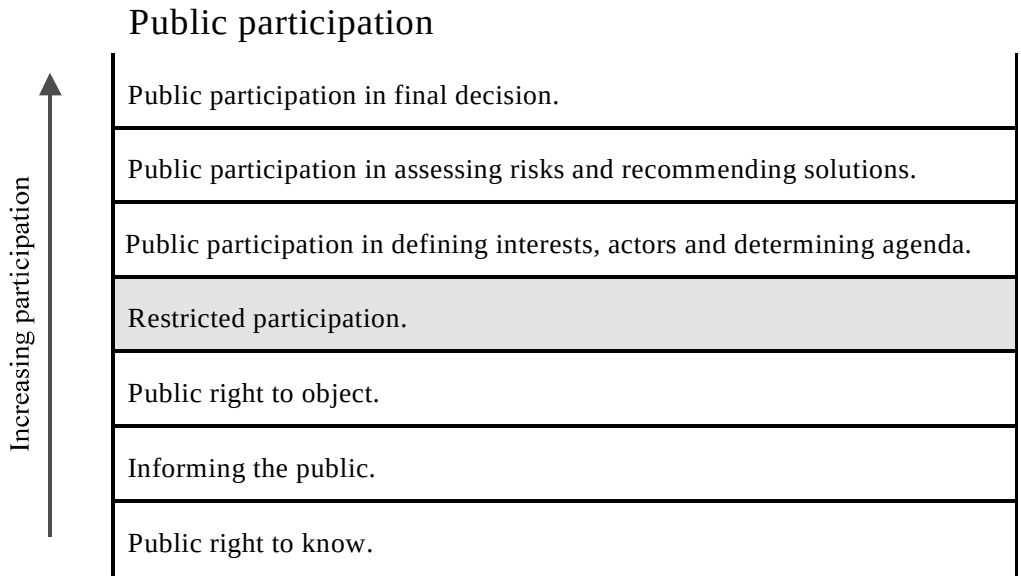
A high degree of trust and transparency needs to be established and maintained within the public realm, to give web-based public participatory processes legitimacy and accountability. There is still very little research on the level of trust the public places on information they come across on the Internet. Some preliminary research recently undertaken suggests that some sectors of society place more trust in information on the web than in certain magazines or newspapers (Carver *et al.*, 2000). However, a great deal more work is required in this area. If nobody trusts the information on the Internet, what use is it?

Traditionally, public participation has been limited to the right to know, to information campaigns and to the right to object through the system of local

political representatives and public inquiries. The lower half of the graph depicted in Figure 4.2 expresses this. The ability to define interests, determine the agenda, assess risks, recommend solutions and take part in the final decision has largely been closed to the public. The opening-up of decision-making processes via web-based approaches may help push public involvement further up the participation ladder as defined by Weidemann and Femers, that is, up from the restricted participation that characterises public involvement in nuclear energy matters today (Weidemann and Femers, 1993). The upper half of the graph depicted in Figure 4.2 expresses this.

Just how far the public should be allowed to climb up this ladder, in the context of decision making about nuclear energy, is a point for discussion by individual countries and their nuclear organisations. In some instances, however, events in the public arena are already taking public participation above the point of restricted participation.

Figure 4.2. The public participation ladder



Source: Adaptation from Weidemann and Femers, 1993.

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5. DEVELOPMENTS IN DECISION-MAKING RESEARCH

Introduction

In this chapter, some broad guidelines are given for the choice of procedures that support decisions, such as those encountered in the nuclear energy sector, through an overview of recent developments in decision-making research. In particular those developments are addressed that focus on the practicalities of institutional frameworks designed to support decision making. Also, alternative decision processes are assessed, that may operate within these institutional frameworks. Topics such as consultation, risk perception and risk communication are directly relevant for this subject matter, and can inform the discussion in an instructive manner. While not constituting main subjects of this chapter, and remaining to a fair extent in the background, especially in first instance, they will be referred to repeatedly.

The context is described – from a decision perspective – in which complex public decisions currently take place, and the limitations that this context imposes at present are explained. Recent findings are reported on what, in this area, is termed *prescriptive* decision research and practice, and some of the principal types of available decision support procedures that fit the needs of decision making in the nuclear energy sector are described. Recent *descriptive* decision research regarding ways individuals and groups interpret judgement and decision-making tasks, are used as a basis on which warnings are given against the dangers of making overly simplistic assumptions in relation to decision making and public involvement in decision-making processes.

Institutional decision-making processes

A substantial number of decisions in the nuclear energy sector are the subject of international, as well as national and more local, concerns. This chapter, however, will devote relatively little attention to the international dimension of decision making. The main reason for this is the fact that decision research has relatively few insights to offer about international decision

processes. This is arguably a reflection of the relatively undeveloped state of international governance in overseeing areas of activity that pose substantial international concerns. Still, in some respects, the nuclear energy sector seems more advanced in recognising some of its international dimensions, in comparison to many other sectors. Analysing contexts through which structured support to better decision making can be provided is the primary focus of decision research.

Largely confirming the above, Underdal (2001) has argued that, whereas there are democratic mechanisms operating *within* nation states, institutional mechanisms for governance at the international level are typically weak. This includes governance at the regional level, which is generally equally poor. In this respect, the recent progress at the European level can be considered an exception to some extent. As a result, many international agreements tend towards a consensus-driven lack of ambition, rather than anything that might be regarded, for example, as welfare optimising.

Related to this matter is the existence of large gaps between the socially and economically central nations and those on the periphery. These differences create not only unequal opportunities, but can also generate radically diverging perspectives. In the international scene, deviating – or even conflicting – perspectives render decision-making processes regarding issues of international concern more difficult. The 2000-2001 negotiations on the signing of the Kyoto Protocol have demonstrated this. Diverging perspectives can also affect attitudes towards risk, both in terms of potential gains to be obtained and losses to be incurred. As such, to give a concrete example, attitudes towards the risks involved with the long-term disposal of radioactive waste can be subject to substantial differences, seen from a global geographical perspective. Indeed, it is known through what is called "prospect theory" (see, e.g. Kahneman and Tversky, 2000), that diverging perspectives can substantially influence propensity to risk-taking. Often an inverse correlation seems to exist between exposure to risk and response capability. A country that is more able, e.g. financially, to reduce certain risks, is likely to accept less readily a given level of risk exposure, in comparison to a country which has no means to reduce that risk exposure. As a result of diverging economic and social development, as well as perspectives, asymmetries between countries in bargaining power can be substantial.

In operational terms, there seems little value in directly pursuing decisional insights in terms of international levels of activity. Overall, there tends to be a weak sense of community, particularly at the global level. International agreements tend to focus on procedural obligations, principally information exchange, and tend not to revolve around ways to reach

internationally agreed positions on individual problems, irrespective of the need, e.g. in view of the environmental challenges humanity faces today. Unfortunately, opportunities for formalised support to decision making at the international level are limited. Arguably, more promising levels at which to analyse decision-making procedures are within nation states. In addition, a perspective worth assessing is the technical one, for which specialists can provide valuable input to decision making. On these levels, there does seem to be a reasonable prospect that perspectives obtained through decision research can be helpful and effective in practice.

Irrespective of the particular institutional arrangements within a given country, decision making in the nuclear energy sector essentially requires ex-ante public policy evaluation. Even if the decision maker may be nominally a private company (such as Cogéma in France, or BNFL in the United Kingdom) any substantial decision is in practice one with public policy implications. Evaluation in public policy is complex and deeply problematic in both theory and practice (see, e.g. Parsons, 2000). Because evaluation is, evidently, about valuing, different stakeholders bring to task potentially quite different frames of reference. Evaluation is ultimately about integrating these frames of reference, not necessarily in the sense of reducing them to a single point of view, but, rather, in the sense of clarifying the values which knowledge in, for and of the policy process embodies (for ideas useful in this context, see, e.g. Lasswell, 1958).

Parsons (2000) sets out a number of principal analytical frameworks for evaluation, while recognising that there are arguably many more: neo-classical economics, experimentalism, managerialism, public choice, pragmatism, interpretivism, experimentalism, evaluation through the price system, and critical realism. Each entails different assumptions. As Giorgi and Tandon (2000) have argued "… mainstream approaches to evaluation, like neo-classical economics or public choice, are concerned with the systematic compilation and analysis of "scientific" types of knowledge – they insist on the importance of causal relationships that can be objectively verified, and are keen on quantification or on tools that allow for quantification; in other words they are positivistic and rely on instrumental rationality. Non-mainstream approaches like interpretivism or critical realism operate, instead, with a post-positivist framework, and are more keen on recovering interactions and interrelations, and less insisting on quantification, or the use of statistical methods or mathematical models."

If one attempts to achieve a better understanding of society's interactions with nuclear energy, the principal message that seems to emerge, in terms of public policy evaluation and support to better decision making, is that the

subject matter should be viewed in a perspective as broad as possible. Good decision making is a matter of good process. Good process should recognise a diverse range of framings of any problem, all of which may have legitimacy and value. For example, even in the technocratic arena of transport planning, part of the drafting process for the 1998 Dutch national transport plan was based on an essentially interpretivist input, involving some 80 participants together clarifying the policy implications that followed from different frames of reference (see Parsons, 2000).

The potential contribution of decision research is to complement the insights, about institutional frameworks and processes, of political and administrative scientists such as Parsons. These can be complemented through a focus on how individuals and groups tackle decision making, in particular regarding issues such as those encountered in the nuclear energy sector. It potentially spans a wide field, from the understanding of perceptions and responses to risk, to the development of formal, normative and prescriptive models to support choices between available policy alternatives. Approaches to decision support, in Parsons' terms, lie broadly in the intersection between neo-classical economics and public choice. They are an important input to decision making in the nuclear energy context, not simply as formal support tools, but also for the way they can be used as facilitative devices in some of the more participative and non-mainstream approaches to policy making, such as stakeholder dialogue.

Decision-support processes

Methods of evaluation directly linked to money

Formal, normative and prescriptive models, or procedures, exist to support decision making. Provided it is recognised that these procedures can constitute support for developing a better understanding of the choices faced – and are not interpreted as tools for the actual making of the decision itself – many good reasons exist for seeking to use such procedures. Prescriptive methods include financial analysis, cost-effectiveness analysis, cost-benefit analysis and decision analysis. The last of these, decision analysis and applied decision theory, will be of main focus here.

Typically, organisations, whether in the public or private sector, seek to evaluate decisions about major projects or policies in monetary terms. They may undertake financial analyses, in which the flows of costs and revenues accruing directly to the organisation that undertakes the evaluation are the only

ones really considered. The key question is whether the net revenues exceed the net costs by a sufficient amount, that is, such that undertaking the project under consideration is attractive. In addition to expressions like the net present value of the required investments and resulting profits, or similar indicators for project attractiveness, the organisation needs to bear in mind such factors as cash flow profiles, risk profiles, and the intrinsic competitiveness of the use of scarce funds and managerial time.

In the public sector, other considerations may prevail. Even here, however, financial analyses may well constitute an important input to overall evaluation. Often, many of the consequences of public expenditures manifest themselves in forms that do not directly lead to revenue flows. Thus, assessing the benefits of public expenditures must also be approached in different, and complementary, ways. In some cases, e.g. where the output of expenditures considered is roughly the same between all the options at hand, cost-effectiveness analysis can be employed. Where this is not the case, cost-benefit analysis is an alternative (see, for example, Pearce and Nash, 1981, and Sugden and Williams, 1978). Cost-benefit analysis seeks to evaluate all possible future impacts of implementing a project, in terms of its social opportunity cost. It bases its choice among alternatives on the overall sum of both the costs and benefits involved. It has a number of strong attractions as a base for assessing potential public expenditure, and is commonly applied, for example in the transport sector. It also has various disadvantages. Among these are problems in dealing with the distribution of impacts, both spatially and socially, and difficulties in establishing monetary values for many crucial environmental and social impacts (see e.g. Dodgson *et al*., 2000). Also problematic can be the broad acceptance of existing and future distributions of income, and hence buying power, in view of attempts to establish desirable societal values. Disputes could emerge over the handling of all sorts of inter-generational effects, an appropriate example of which is the disposition of long-lived radioactive waste in the case of nuclear energy. Furthermore, it could prove tedious, or even impossible, to reflect decision makers' objectives, when these differ from those implied by market forces. The slow instalment and diffusion of environmentally beneficent, but rather expensive, energy technologies is a good example in case.

Multi-criteria decision support

Monetary-based assessments of public policy alternatives are often a central, and necessary, part of a search for well-informed decisions. Arguably, however, they are not sufficient to ensure that a multi-faceted understanding of public policy alternatives, which is increasingly required today, is obtained.

Multi-criteria assessments offer an additional perspective. There are many distinct multi-criteria approaches, responding to a number of different types of potential application, in terms of, for example:

- the time available to undertake the analysis;
- the amount or nature of data available to support the analysis;
- the analytical skills of those undertaking the analysis and making the decision; or
- the administrative culture and requirements of the organisation involved.

It seems appropriate to concentrate on multi-criteria approaches that offer a good combination of a number of relevant elements. Among these desirable characteristics are internal consistency and logical soundness, transparency, ease of use, data requirements consistent with the importance of the issue considered, realistic time and manpower resource requirements for the analysis process, ability to provide an audit trail, and, possibly, software availability. For a wider overview of multi-criteria approaches, see Dodgson *et al.* (2000).

The first concern, common in fact to all methods discussed here, is to identify the decision makers' objectives. Subsequently, it is a matter to respond to these objectives, and determine the particular decision support structure that can be provided. Also, even when the most structured and formalised decision support systems can be applied, emphasis should be laid on the decision process, rather than on some rigid decision support structure. The proposed and applied procedures should predominantly be seen as a way to facilitate the shared understanding of the choice faced, as well as of the alternatives that are available.

Decisions in the energy sector in general, and in the nuclear energy sector in particular, are often complex and surrounded by uncertainties. It is known that man is often not a good intuitive processor of such decisions (see, e.g. Simon, 1957, and Kahneman and Tversky, 2000). Therefore, some form of decision support seems both desirable and necessary. To the extent that monetary methods can fail to capture all key features relevant to a particular decision faced, multi-criteria methods offer an alternative. They can be characterised by a number of facets, all of which constitute potentially important inputs to the effective development, as well as defence, of public policy choices. Multi-criteria methods are open and explicit, and can provide an audit trail and a means of communication within the decision-making body as well as between that body and the wider community. In multi-criteria

approaches the choice of objectives and criteria is open to analysis, and these criteria can be changed if they are felt to be inappropriate; scores and weights can be made explicit, developed according to established techniques, and cross-referenced to other sources of information; and performance measurement can be sub-contracted to experts, and need not necessarily be left in the hands of the decision-making body itself.

Implementing multi-criteria decision support

Implementations of multi-criteria decision support tools are becoming more and more common, as familiarity with multi-criteria decision support methods grows, and as the quality and flexibility of software to support larger implementations of these tools have grown. Central to most applications is what may be seen as a performance matrix, or evaluation framework, in which each row describes an alternative, and each column describes performance against a criterion judged to be relevant to the decision context under consideration. Frameworks of this type are often integral to public policy choices, for example the NATA (New Approach To Appraisal) framework, introduced by the then UK Department of the Environment, Transport and the Regions. NATA was a procedure for assessing major inter-urban road schemes, which involved completion of a multi-criteria framework reporting a range of impacts, among which environmental, safety, economic impact, accessibility and degree of integration with strategic transport plans, as well as a full cost-benefit analysis (see, for example, DETR, www.detr.gov.uk). In multi-criteria decision support systems, performance assessment may be numerical, but can also be qualitative.

The attraction of an evaluation framework is that it helps overcome Simon's concern about man's limited intuitive decision-making capabilities, by setting out an explicit frame of reference. Against this frame of reference, all alternatives are judged in a consistent fashion. The evaluation framework may repeatedly be re-visited and adapted, while remaining a point of reference in judging the various alternatives. Sometimes, direct analysis of the framework alone will be enough to indicate which is the correct alternative to select, either because it is technically dominant in terms of performance, or because the framework has clarified the relative strength of the alternatives sufficiently, i.e. such that consensus can easily be reached. In those cases where insufficient clarification is reached, it is possible to move ahead to a more formal numerically-based analysis, in which all performance assessments, including those initially made in qualitative terms, are converted into assessments in which alternatives are qualified on a scale from 0 to 100. Subsequently, the performance on individual scales is aggregated, using weights, to create

aggregate performance scores that may then be used to support final judgements about which alternative to choose.

It is important to point out that there is no single normative model, that is without critics, even of how individuals, let alone groups, should make multi-criteria choices. The one that comes closest to universal acceptance is based on multi-attribute utility theory, which is derived from the work of von Neumann and Morgenstern (1947), and Savage (1954). However, the principles in this theory are not readily applicable to practical problems. Critical here is the work of Keeney and Raiffa (1976), who developed a set of procedures, consistent with the earlier normative foundations, that allow decision makers to evaluate multi-criteria options in practice. Even their rather well-known method, however, although applied to many real-life decisions faced in both the private and public sector, is relatively complex. Specialists on major projects are best capable to implement it, that is, if time and expertise are both necessary and available. For example, it formed a core part of the analysis of the US government's assessment of the feasibility of the Yucca Mountain radioactive waste repository. The Keeney and Raiffa approach can, more generally, be used to support decisions of a very diverse nature in the energy sector (for a broad perspective on this, see Keeney, 1980).

What makes the Keeney and Raiffa model potentially demanding to apply is, firstly, that it takes uncertainty formally into account, building it directly into decision support models. Secondly, it allows attributes to interact with each other in ways other than a simple, additive fashion. In certain circumstances, it can be important to build into the analysis one or both of these factors. In practice, however, it often may be better to ignore them, in order to allow a simpler decision process. What results is a simple linear model, created by multiplying the value score for each criterion by the weight of that criterion, and then adding all those weighted scores together.

Models of this type have a well-established record of providing robust and effective support to decision makers working on a range of problems and in various circumstances. They have an adequate theoretical foundation and an ability to diminish the cognitive limitations of unaided decision makers. They are often referred to as MADA (Multi Attribute Decision Analysis) models. Their most important feature is probably that they are sufficiently simple and transparent to be used as part of a process of consultation with stakeholders. These stakeholders may be internal to the organisation, but may also be external. MADA models are often employed as the analytical base for decision conferences, or for the types of stakeholder dialogue that may benefit from having a capability to estimate the aggregate performance of alternatives, in terms of the stated objectives of the stakeholders.

Implementing a MADA

A full description of how to implement a MADA process is given in Dodgson *et al*. (2000) and is beyond the scope of this chapter. Schematically, the principal steps in a MADA application typically are the following:

- The decision context is established, and questions are addressed, e.g. what are the aims of the analysis, and who are the decision makers and key stakeholders?
- The various alternatives are identified.
- The objectives and criteria are identified that reflect the value associated with the consequences of each alternative.
- The expected performance of each alternative is described against these criteria, that is, the performance matrix is created.
- Weights are assigned to each of the criteria, in order to reflect their relative importance to the decision.
- The weights are combined, as well as the scores for each of the alternatives, in order to derive an overall value.
- The results are examined.
- An analysis is conducted on the sensitivity of the results to changes in scores and/or weights.

In implementing the steps, it is important not to see them as a simple linear process to be worked through once, sequentially, with an answer emerging at the conclusion. Rather, a good MADA process is likely to involve substantial iteration, with feedback to earlier steps. For example, after the initial estimation of the performance matrix, it may well be desirable to revisit the initial list of alternatives, to fine-tune existing alternatives, or to create new ones in the light of the insights gained from the initial performance assessment. Many elements of the MADA process have substantial technical content and need to be undertaken with care, according to properly laid down procedures. This is particularly true for the weight assessment step. However, most practical experience with MADA indicates that the main value added to decision making comes through its influence on the process of identifying, characterising and understanding the full range of implications of the available alternatives, rather than through its more formal aspects.

The MADA framework can also be usefully employed purely as an exploratory device to learn more about stakeholder viewpoints. For some public

policy questions, diversity of views and other political, social and scientific factors surrounding an issue may make it unrealistic, or at least premature, to move directly to an identification of a preferred policy action. The MADA approach may be used to generate a better understanding of the reasons for divergences in viewpoints, and to provide an opinion-map of the question under debate. It may even suggest ways forward that may be mutually acceptable to stakeholder groups whose fundamental viewpoints are opposed to one another. One example regarding this function of the MADA approach is the case of genetically modified (GM) crops, specifically the use of GM herbicide tolerance and the use of strategies for the cultivation of oilseed rape (see Stirling and Mayer, 1999). The aim of their study was not to identify a single strategy option. Rather, it used the MADA structure as a tool for mapping the debate on the risks potentially surrounding the introduction of such crops. Unlike some other risk assessment procedures, the process used did not focus directly on risks, but sought to throw light on them in an indirect manner, by examining the perceived relative performance of the options and the underlying causes of the differences in view.

MADA may also usefully be embedded in wider analyses of organisational strategy and action. It is important to recognise that well-supported decision making is, for most organisations, just one part of a broader picture. In particular, it must be embedded in strategies for implementation and action planning. No matter how good the decision is, if it cannot be implemented, or, more likely, when some key stakeholders are unwilling to implement it, it is of little practical value. For example, in the context of the strategic planning for the extension of transport corridors to Eastern Europe, the CODE-TEN research project devised a series of interlocking decision support procedures. These procedures included a MADA element, but also had a section specifically targeted at the identification of barriers to implementation, and the ways to remove or get around these barriers (Tandon and Giorgi, 2000). CODE-TEN was the name of a European Union research project: Strategic Assessment of Corridor Developments, TEN Improvements and Extensions to the CEEC/CIS. The primary objective of CODE-TEN was to develop a strategic policy assessment methodology that could be applied to assess the impacts of the development of Pan-European corridors. The methodology developed, the DECODE method, combines top-down and bottom-up approaches. It applies the scenario approach in order to elaborate consistent “images” of the future that combine information on three aspects: socio-economic development, policy development and infrastructure planning. These images are then subjected to impact assessment to help in decision making.

At another level, planning techniques such as the Strategic Choice Approach lay particular emphasis not only on identification and choice of an

alternative to implement, but also on developing action plans that ensure successful implementation (Friend and Hickling, 1997). Such plans can, for example, provide a way to deal with doubts and uncertainties, by facilitating a staged implementation of a given strategy. Such a staged implementation allows less contentious elements to be introduced first, while an explicit search for further information, or simply the passage of time, may allow more straightforward execution of more difficult aspects at a later stage. The MADA approach is entirely consistent with this type of approach to implementation. Indeed, the two complement each other well, since the Strategic Choice Approach gives particular prominence to uncertainty and its consequences. MADA, on the other hand, is more straightforwardly implemented by taking a relatively simple approach to uncertainty, which usually does not capture all the subtleties of what the risks are and how different stakeholders perceive them. As emphasised earlier, effective evaluation depends upon drawing together several frames of reference. Linking together different tools to support evaluation and associated activities can be central to this process of integration.

Formal support to group decision making

MADA, and related but more technically complex implementations through multi-attribute utility analysis, are all in principle founded on the objectives and value judgements of a single individual. Just as economics has problems with inter-personal comparisons of utility, and thus with proving that any chosen policy is socially optimal, so too do frames of analysis developed with subjective expected utility models. In practice, this is not a fatal weakness, however, since much of the data in MADA analyses are only approximate. The data related to forecasts of environmental impacts of e.g. energy use, and those concerning future socio-economic conditions, are good examples in case. Also, the emphasis is, in any case, on supporting a decision process, not on developing a totally prescriptive outcome on the basis of a formal model. Nonetheless, the question of formally supporting group decisions deserves some attention, because including group aspects can bring up some specific, and relevant, behavioural issues. It also deserves attention because today various readily accessible computer-based group decision support procedures are available. It is important for organisations, much of whose decision making is group-based, to understand the capabilities, and the limitations, of these group decision procedures. A Group Support System (GSS) may support many different aspects of the overall decision process. A recent report identifies nine core functions (Bown *et al*., 2000):

- Constructing computer-driven agendas for meetings.

- Electronic brainstorming or concept generation.
- Ranking and voting on ideas.
- Categorisation of ideas and concepts.
- Organisation of ideas into alternatives and criteria.
- Individual decision analysis.
- Group decision analysis.
- Sensitivity testing.
- Report generation.

The Bown report, however, fails to uncover much substantial evidence to support the proposition that a GSS, in and of itself, improves decision making. To some extent this is understandable, since the evidence for the effectiveness of group processes is notoriously difficult to gather in a rigorous way. Even when combined with informal knowledge of group decision support in practice, and with some of what is known about individual and group decision making, the evidence collected so far suggests that a cautious attitude towards the claims of GSS is currently appropriate. Relatively easily a false and ill-founded sense of confidence comes to light about the results produced by computerised procedures. While some of the better software packages probably possess the capability to enhance group decision making, effective decision support requires more than these packages alone can presently offer. The need for effective facilitation of the whole 8-step MADA process is critical, while this process ought to be backed up by an experienced understanding of the interaction between a variety of factors, among which GSS, the various decision tasks, the characteristics of the decision-making group, and the decision context.

Overall assessment of decision-support procedures

Complex organisational and public policy decisions can benefit substantially from carefully applied formal decision support. There is ample evidence to suggest that individual judgements of risk are often error-prone, and that, even in circumstances where risk is not a central feature, man's limited information processing capacity makes him an inadequate intuitive processor of complex decisions. Here, formal decision support systems can come to the rescue. Many forms of formal support procedures are available that can help individuals and groups to better understand complex decisions in the face of multiple attributes and risk. Monetary-based procedures, such as cost-benefit analysis, have an important part to play. However, in the spirit of seeking to

integrate multiple perspectives on contentious social questions, the monetary perspective alone will frequently not be sufficient. Multi-criteria decision analyses can provide an important complement to the monetary perspective.

There are many different multi-criteria decision support processes available. Some possess a strong axiomatic basis in individual choice behaviour. Others are more pragmatic in their origins. The best multi-criteria decision support processes offer a sensible balance of the two, recognising that no model can hope to capture all the nuances of a decision situation, and that decision making itself is practically always embedded in wider organisational processes. Well-undertaken applications of procedures like MADA can offer substantial and effective support for decision making, not only to the decision itself, but also in a wider context. The latter follows, because the extra understanding of and commitment to the outcome that these procedures can generate can be useful vis-à-vis wider questions of choice implementation. If a more considered and technical analysis is desirable, and can be justified by the importance of the decision, the application of multi-attribute decision analysis, based on the procedures derived by Keeney and Raiffa, can be quite effective.

Behavioural perspectives on supporting decision making

One of the primary justifications for using the procedures identified above is that unaided human decision making is often subject to important limitations that can lead to error and bias. Here, we briefly describe three such examples of primary limitations, and the implications they have for decision making in the nuclear domain.

A first limitation has been demonstrated by research, which has consistently shown that people's capacity for thinking is limited, and that, in order to choose in complex situations, they have developed simple modes of reasoning, often referred to as heuristics. For example, Simon (1957) argued that people "satisfice", implying a decision heuristic that involves choosing the first alternative that meets their minimum requirements, rather than choosing the best from all alternatives on offer. The latter is typically advocated by rational theories of decision making. "Satisficing" is relatively simple, in terms of its cognitive operations, and therefore makes rather low demands on scarce mental resources. However, it may lead to sub-optimal behaviour, given that, once an "acceptable" option is found, the search for and evaluation of further alternatives ceases. Better options that have not been considered at some early point in time may be further ignored at later stages (see Svenson, 1979, and Payne, Bettman and Johnson, 1993, for examples of other decision heuristics). People may also use so-called judgmental heuristics, when assessing risk and

uncertainty (Kahneman, Slovic and Tversky, 1982). For example, people often judge the likelihood of some event happening in the future in terms of how easily instances of it happening in the past can be brought to mind. This heuristic, called "availability", is a simple thinking routine that provides a fast and generally accurate way of forecasting the likelihood of future events. However, it can lead to inaccurate judgements, with people overestimating the likelihood of particularly dramatic hazards, e.g. nuclear accidents, and underestimating the likelihood of unremarkable hazards, e.g. stomach cancer (see Bazerman, 1998). This explains, in part, why public aversion to hazards does not always accord with scientific risk assessments.

Heuristic thinking also commonly occurs to experts. For instance, it has been shown to underpin the strategy formulation process of senior managers in a broad range of organisations and, on occasions, has led to poor decision making that had damaging effects on these organisations (Schwenk, 1984, 1995; Das and Teng, 1999; Maule and Hodgkinson, in press). One advantage of the decision aiding procedures described earlier is that they prescribe the processes of judgement and decision making that should be followed and, in doing so, limit the use of simple decision heuristics. In addition, these procedures break the process down into separate stages, each of which place manageable demands on decision makers, thereby reducing the need for these simplistic modes of thinking. However, many of the prescriptive procedures described above involve human judgement, without prescribing the process to be followed. Hence, they may be vulnerable to the effects of simplifying heuristics. For these situations, it is appropriate to train people to think more effectively (for suggestions about how to help people make better judgements see Russo and Shoemaker, 1989; Bazerman, 1998; Kahneman *et al*. 1982).

A second limitation on human decision making concerns the stability of human preferences. There has been a generally held belief by policy makers, as well as those analysts advocating the use of rational decision-making models, that people hold stable values, which can be measured reliably. From this standpoint, eliciting the values held by key stakeholders (including the public) and using these to inform final decision making, is a key element in determining effective and acceptable policy decisions. However, recent research (see Slovic, 1995, for a brief review) suggests that human values are labile. Put simply, people do not always have stable values, and the method used for eliciting values can crucially determine how these values are expressed. This can lead to many anomalies in decision making.

For instance, people may judge one option to be worth more in monetary terms than another, but when asked to choose between them, may still choose the option that they had given the lower monetary value (Slovic *et al*., 1990).

One reason for such an anomaly is that judging values and choosing between options are different mental activities, which lead people to focus on different aspects of the information that describe the options. Thus, in the policy domain, eliciting the public's values may not always predict their preferred choice. Further, these studies strongly suggest that assessments of stakeholder preferences need to be treated with caution, and that it is important to ensure that the methods used for eliciting the preferences of the public and other stakeholders are chosen carefully. These findings have important implications in the domain of public policy and nuclear energy decision making, given the increasing commitment to taking account of public and other stakeholder values. They suggest that techniques such as contingent valuation (Mitchell and Carson, 1989), that depend upon eliciting human values, need to be treated with a certain caution (see also Kahneman and Knetsch, 1992).

A third limitation concerns the effectiveness of group decision making. Many important decisions are assigned to groups, because they are assumed to be more effective than individuals. Potential advantages include that groups are more informed than any single individual, and more creative and more watchful to error, while group activity can be more motivating than working alone (see Baron, Kerr and Miller, 1992). However, these advantages are often not realised because of limitations in the group decision-making process. These limitations and the adverse effect they have on decision effectiveness are well documented. For instance, unequal power relations between group members often imply that some individuals dominate, even though they are not the ones who have the greatest knowledge or understanding. In addition, groups rarely consider which decision rule they are using (e.g. unanimity, where all must agree, versus majority) or the implications on the final outcome and its acceptability that the implicitly used rule might have (Miller, 1989). Janis (1989) has documented a set of conditions, under which groups are likely to make bad decisions. He argues that these conditions have led to poor decisions in a number of high profile policy situations in the United States, such as in the Watergate scandal and the failure to protect itself against the attack on Pearl Harbour. These conditions, he states, commonly occur, whereby he suggests that many policy decisions are vulnerable to such negative effects.

Many important decisions about nuclear energy, including those using prescriptive approaches similar to those described above, are taken by groups that have little understanding about effective group processes, or about how the potential advantages that groups possess can be realised, and their limitations overcome. There are, however, a variety of group techniques that have been developed to overcome these constraints (see Ferrell, 1989, for a broad review). Some techniques involve structuring the group discussion, so as to avoid known biases. An example is the Delphi technique, which involves anonymous

interactions that can surmount the negative effects of unequal power relations. Others involve teaching individuals appropriate group decision-making skills (Hall and Watson). These techniques have considerable potential for improving group choice processes in nuclear energy decision making, yet are rarely adopted.

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6. REVIEW OF PUBLIC OPINION SURVEYS IN SOME MEMBER COUNTRIES

Introduction

Public opinion surveys are one of the means to assess how society relates to a wide range of issues, including technological development and the implementation of large industrial projects. In the field of nuclear energy, opinion polls have been conducted on a regular basis in most of the countries where nuclear power programmes have been developed. This chapter aims at drawing findings from public opinion polls performed in member countries, in order to illustrate public behaviour and reactions related to nuclear energy. For the purpose of the present study, a limited number of opinion polls carried out in a selected number of member countries – Finland, France, Germany, Japan, the United Kingdom and the United States – are reviewed and their main results summarised.

The chapter starts with an analysis of a number of characteristics of opinion polls in general, as well as the nature of the polls reviewed for this study. The next section presents some overall findings drawn from the opinion surveys reviewed, the remainder of the chapter briefly presents the main results on a series of key questions. Those questions are selected in the light of their relevance to various aspects of public opinion on nuclear energy, and for each of them the main elements of responses from each of the polls considered are presented. Opinions on various forms of energy are reviewed and specific views on nuclear energy analysed. Differences between different population groups in attitudes towards nuclear energy are investigated as well as specific opinions on the future of nuclear energy. Some of the aspects of nuclear energy that raise special concern are addressed. The issue of public participation in decision making for nuclear projects, dealt with extensively elsewhere in this report, is briefly mentioned. Finally, public confidence and trust in the information on nuclear energy provided by various entities are described.

Opinion polls

The member countries selected – six out of seventeen where nuclear electricity is produced – cover a variety of contexts regarding nuclear energy programming and development, ranging from continued growth, e.g. Japan, to accelerated phase-out, e.g. Germany. The polls reviewed below, however, do not pretend to reflect the full range of status and trends in all member countries. For example, opinion surveys have not been conducted recently in countries such as Italy and the Netherlands, where nuclear energy has been abandoned, or will most likely be phased out soon. Since only a limited number of polls have been reviewed within the present study, the findings presented below are by no means exhaustive.

The surveys reviewed and analysed in this chapter, carried out during the period 1997-2001, were conducted by governmental bodies, non-governmental organisations and private companies involved in nuclear energy applications and development. Experience shows that results from opinion polls are sensitive to a number of factors, including the method used, the type and list of questions employed, and the public involved. Since in the polls reviewed below the choices of methods, questions and audience are made by the organisations performing the survey, which all have some connection to the nuclear industry, the results presented in this study may differ from those of public opinion polls that would have been conducted by organisations entirely independent from the nuclear energy sector.

Another important limitation of the analysis carried out below is that each poll considered has its own structure and list of questions. Although the issues addressed in the surveys selected are similar, there are diverging nuances in the formulation of the questions involved. It is likely that these differences or diverging nuances in the questions posed, had an impact on the responses given. Needless to say, opinions vary over time. Given the different points in time at which the various polls were executed, differences in the answers provided may have arisen as a result of a mere asynchrony. Therefore, it is difficult to draw generic findings and conclusions from the polls reviewed. Nonetheless, an attempt to do so is described below, since it is thought that a number of useful elements can be distinguished and should be displayed.

As a hint for future work in this area, and to compensate for the caveats made above, it would be helpful to perform a targeted public opinion poll in interested member countries using an agreed common methodology and an homogeneous set of questions. This poll, potentially restricted to e.g. EU countries, or possibly extended to countries outside the OECD framework, would need to be performed at one point in time, and preferably be realised by

an institution with as small as possible connection to the nuclear industry. This could consolidate the findings of the present study and could ensure a comparability between the answers given in opinion polls in different countries, as well as a better consistency of results in various member countries. Such a survey could be conducted by relevant national organisations, preferably supervised by one single organisation, and potentially under the auspices of the NEA.

General findings

A number of generic points, listed below, are emerging from the review of the public opinion surveys that have been considered within the present study. Although the polls reviewed may not be representative of the wealth of data and information available in the literature, those general findings, presented below, are thought to be indicative of overall trends.

This review of feedback from experience in various countries provides elements for a better understanding of similarities and differences between countries and the rationale behind those differences. Key issues in this regard include country specific cultural backgrounds, behavioural attitudes, global energy policy situation and the role of nuclear energy in the overall domestic supply.

Attitudes of the public towards nuclear energy do not seem to be tightly correlated with the nuclear energy policy of the country. Indeed, some of the polls reviewed reflect striking contrasts between public opinion towards nuclear energy and the role of nuclear energy in national/governmental energy policies, e.g. majority of opinions favourable to nuclear energy in countries where it has been decided to phase-out nuclear power plants.

The main generic concerns of the public about nuclear energy, according to the surveys reviewed, include safety and radioactive waste management and disposal. Concerns are expressed in particular regarding the adequacy and reliability of the information provided to the public on nuclear safety, especially in case of major incident or accident, and on the local impacts of radioactive waste repositories.

While the role of nuclear energy in protecting air quality generally is acknowledged by the public, its contribution to alleviating the risk of global climate change does not seem to influence significantly its acceptance by the public. Increasing public concerns about health and environmental risks in the

last decades do not seem to have affected significantly public opinion about nuclear energy, either positively or negatively.

According to most public opinion surveys reviewed for this study, nuclear energy is seldom associated with environmental protection and sustainable development goals. Renewable energy sources, such as solar and wind power, and to a lesser extent gas are considered “green”, benign for the environment and harmless for human health. On the other hand, nuclear energy is not often quoted as environmentally friendly.

Energy prices and price stability, as well as security of supply, remain important issues for the public according to most surveys and, in this context, the role of nuclear energy is generally acknowledged.

Attitudes towards various energy forms

As noted above, it seems that public opinion on various energy sources is largely independent of the energy supply structure in the country. Irrespective of the shares of different sources in national energy supply, people generally prefer sources perceived as environmentally benign although security of supply seems to be a concern for most respondents according to the polls reviewed for this study.

Even in countries where nuclear energy accounts for one third or more of the energy supply, some people do not fully accept its use and look forward to the future development of alternatives perceived as less environmentally damaging. However, almost all respondents consider nuclear power as more benign than coal-fired power because it does not emit carbon dioxide.

Some of the results of the opinion polls reviewed for the study are presented below. Data on energy supply structure in the countries considered are provided also whenever relevant to illustrate the point made above, i.e. absence of link between role of nuclear energy and its perception by the public.

In Finland, nuclear power and hydropower are the main sources of electricity supply. The shares of various sources in electricity generation in 1998 were: coal (19.3%), oil (1.6%), gas (12.6%), nuclear power (31.1%), hydropower (21.4%) and others (13.9%). Respondents to a poll carried out in 1999 expressed a preference for hydropower, followed by peat and natural gas. More than half (55%) of the persons consulted stated that they would have liked the share of coal in energy supply to decrease.

According to the same survey, viewpoints about nuclear power were rather polarised and public opinion was strongly divided on this topic. About one third of the respondents (34%) were in favour of an increase in nuclear power capacity while about the same proportion (36%) were favourable to its reduction.

Public opinion was found generally supportive of renewable energy sources such as biomass, solar and wind power. Solar energy was considered a realistic source for supplying pollution-free energy in the near term by 47% of the people consulted while 33% thought that the technology to exploit solar energy will be available economically only in the long term. By comparison with previous opinion polls, it was noted that optimism about solar energy was increasing with time.

Around three quarter (73%) of the respondents expressed the view that wind and solar energy could be developed extensively in Finland rather soon, provided sufficient RD&D efforts would be made on those technologies. On the other hand, around 11% of the respondents thought the contrary.

In France, nuclear power is the main source of electricity supply. The shares of various sources in electricity generation in 1998 were: coal (7.4%), oil (2.3%), gas (1.0%), nuclear power (76.5%), hydropower (12.2%) and others (0.6%). According to a poll carried out in 1997, a large number of respondents considered that nuclear energy will remain an important source of electricity supply in France in the coming decades. Some 62% of the respondents thought that nuclear energy would remain the largest source of electricity supply in France for 10 years and 43% thought that nuclear would remain dominant for 20 years. Some respondents thought that the share of nuclear energy would increase.

Renewables energy sources were considered by a majority of respondents as promising alternatives to fossil fuels and nuclear energy. In terms of protection of the environment, respondents ranked new renewable energy sources first (66%), followed by hydropower (14%), natural gas (6%), nuclear power (5%), coal (4%) and oil (1%).

Coal and nuclear power are the main source of electricity supply in Germany. The shares of various sources in electricity generation in 1998 were: coal (54.2%), nuclear power (29.3%), gas (9.8%), hydropower (3.1%), and oil and others (3.6%). According to a poll carried out in 1999, public concerns about energy included long term security of supply, diversity, low prices, risk avoidance and environmental protection.

The sources of energy that the public thought would make the greatest contribution to German energy supply in the future were, by order of importance: solar energy, natural gas, hydropower, wind energy, nuclear power, oil, imported electricity and coal. It is important to note that, at the time this poll was carried out, nearly half of the persons surveyed had a wrong idea or no idea at all on the actual contribution of nuclear energy and other energy sources in the German supply.

The share of various sources in electricity generation in Japan in 1998 were: coal (19.1%), oil (16.4%), gas (21.1%), nuclear power (32.1%), hydropower (8.9%), and others (2.4%). The opinion poll considered in this study indicates that two thirds of the population are concerned about future energy supply. Nuclear power was considered a main source of energy that would make the greatest contribution to energy supply in the next 10 years. However, half of the respondents favoured renewable energy sources, such as solar energy and wind power, as means to avoid carbon dioxide emissions and many of them expected renewable energy sources to become easy to use in the near future.

According to the poll, the pillars of energy supply during the next decade would be by order of importance: nuclear power, oil, natural gas, renewable energy, hydropower, geothermal, and coal. Within the next 30 years, the ranking of energy supply sources would become: renewable energy sources, nuclear power, hydropower, oil, natural gas, geothermal, and coal.

The shares of energy sources in electricity generation in the United Kingdom in 1998 were: coal (34.5%), gas (32.5%), nuclear power (28.1%), and others (4.9%). In a survey performed in 1998, most of the respondents thought that renewable energy sources and natural gas, followed by nuclear power, will be the main energy sources for electricity generation in the near future, while the role of coal will decrease. However, nearly half of the people polled believed that the country would be making greater use of nuclear energy followed by natural gas and renewable energy sources in next decade.

Coal is the main source of electricity supply in the United States. The shares of various sources in electricity generation in 1998 were: coal (52.7%), oil (3.9%), gas (14.7%), nuclear power (18.8%), hydropower (7.7%), and others (2.2%). A public opinion poll carried out in 2000 indicated that the primary sources of electricity in next decade were expected to be solar and nuclear energy (25% and 24% of the respondents, respectively) followed by hydro-power and natural gas (15% and 11%, respectively). Coal, wind power and oil were not expected to be important sources of electricity in future US supply.

Attitude towards nuclear energy

The attitude towards nuclear energy does not seem to be influenced by the policy of the country, i.e. development, continued use or phase-out of nuclear power. A majority of the public, according to the polls reviewed, considers nuclear energy as a necessary source for the time being but expresses reservation on its continued use in the light of the issues raised regarding nuclear safety and radioactive waste disposal.

Most people, according to the polls reviewed, recognise the importance of nuclear energy to meet rapidly growing demand in the world, especially in developing countries. However, the perceived advantages of nuclear energy in terms of security of supply, economics (cost stability and, in some countries, competitiveness) and environmental protection (no atmospheric pollution) are generally outweighed by its perceived drawbacks in terms of risk of severe accident and burdens associated with radioactive waste management and final disposal.

According to series of polls carried out over long time periods, public attitudes towards nuclear energy change significantly over time and vary with national and international contexts and events. For example, the oil crisis, the Three Mile Island and Chernobyl accidents or the blackouts in California were reflected in the results of public opinion polls on nuclear energy.

In Finland, nuclear power was considered, according to the poll reviewed, to be contributing to economic and reliable energy supply as well as welfare and to reduction of the greenhouse effect. The safety aspect of nuclear power was indicated to be a crucially important factor in its acceptability to the public. More than two thirds (70%) of the respondents regarded nuclear power as a potentially dangerous and risky method of electricity generation.

According to a poll carried out in France in 2000, half of the population believed that nuclear energy would become a source of energy among others, i.e. would play a less important role than at present, while one third of the population believed that nuclear energy would keep its major role. A majority of the French population had a good opinion of nuclear power in the country and wished France to remain a world nuclear industry leader.

French people supported nuclear energy because of its environmental advantages in terms of reducing the risk of global climate change, its contribution to electricity price stability in spite of oil and gas price rises, and its role in enhancing national energy independence.

In spite of an overall positive attitude towards nuclear energy, a large fraction of the French respondents to the poll expressed serious or moderate concerns about the risk of severe accident.

In Germany, as noted above, a poll carried out in 1999 showed that the public was not very well informed about the contribution made by nuclear power in the energy supply of the country. The attitude of the public towards nuclear energy, according to this poll, was rather divided with views ranging from desire for phase-out to favouring construction of new reactors, and there was no decisive majority on any side.

The public was found to support nuclear power in the poll in Japan. Two thirds of the public considered nuclear power as a significant energy source for Japan's electricity supply. The poll showed that about 43% of the respondents were in favour of building new nuclear power plants and 27% were supportive of a continued operation of existing plants. On the other hand, about 20% think nuclear power should be phased-out.

Nevertheless, about 70% of the Japanese respondents felt uneasy about nuclear energy due to the risk of incidents and accidents, insufficient transparency of information, and some recent scandal. Concerns were expressed about safety issues, such as measures for preventing accidents, reliability of the information provided on incidents occurring at nuclear power plants, and radioactive waste management. However, a quarter of the population surveyed showed confidence in nuclear energy, trust in the government and utilities, and viewed nuclear power plants as safe when operated according to good practices.

Recent surveys in the United States indicated that the public was increasingly supportive for nuclear power. There was nearly a consensus on keeping the existing nuclear power plants in operation and renewing the licences of those plants, provided they meet national safety standards. Nearly three quarters of the respondents agreed to keep the option to build more nuclear energy plants in the future and considered that nuclear energy should play a very important or somewhat important role in meeting future electricity needs in the United States. More than three quarters (78%) agreed with the statement: "Considering the electricity shortages in California and other States, electric utilities should prepare now so that new nuclear power plants could be built if needed in the next five years."

At the same time, the surveys showed that information about the clean air benefits of nuclear energy, such as preventing air pollution, increased favourable attitudes, but the majority of the respondents still did not associate spontaneously nuclear power with clean air.

A majority of the public, according to recent polls, has confidence in nuclear safety and recognise performance improvements at nuclear power plants over the past decades.

Differences in attitudes towards nuclear energy between population groups

Generally, men and older people are more supportive of nuclear energy than women and young people. Attitudes towards nuclear energy tend to change over time owing to the information available to people. Many people do not feel very well informed. Opponents to nuclear energy feel less well informed and are less interested in the topic.

One of the polls performed in Finland shows that differences of attitudes towards nuclear power are strongly correlated to both age and sex. For example, nearly half of the men who responded to the poll were supportive of nuclear energy while less than 15% of the women were supportive. The same poll indicated that attitudes towards nuclear energy were increasingly positive as people become older. Also, senior professionals, managers and entrepreneurs expressed more positive opinions on nuclear energy than others.

Similar trends, i.e. more positive attitudes in masculine and older population, were found in Japan and in the United States. A survey in the United States showed public attitude towards nuclear energy depends on the information available about nuclear energy. According to the poll, only 10% felt very well informed about nuclear energy. The younger generation, women and those who oppose nuclear energy felt less well informed than others did. Those who said they were opposed to nuclear energy also felt less well informed about and less interested in the subject.

Attitudes towards the future of nuclear energy

Regarding building new nuclear power plants, the NIMBY syndrome applies perfectly well since, even when people agree on the relevance of building a new nuclear power plant, they don’t want it to be constructed in their neighbourhood but prefer that existing nuclear power plant sites be used.

However, in countries that have adopted a nuclear phase-out policy, there is a gap between the public and government because public opinion polls generally show that a majority of the public is favourable to have existing power plants continuing to operate. Many people foresee a more progressive evolution of the national energy system and expect nuclear energy to be

replaced by renewable sources in due course when they will reach technical and industrial maturity and economic competitiveness.

In Finland the project of constructing a fifth nuclear unit polarises the attention of the public and attitudes towards nuclear power future were found to be centred around this topic. Nearly one third (31%) of the population polled considered that a fifth nuclear power plant should be built, and a little less than half (48%) rejected the idea.

In France, according to the poll reviewed, phase-out of nuclear energy is not envisaged by the population and a large majority is in favour of maintaining in operation for the time being the existing nuclear units. However, likely in recognition that there is no need for additional base load capacity in the country, there was little support for the construction of new nuclear power plants.

The case of Germany illustrates apparent discrepancies between national policy and public opinion, as reflected in polls. According to the poll reviewed for this study, a majority of the German public would like nuclear power plants to continue operating while the government has decided on an accelerated phase-out. A majority of the respondents (62%) considered that phasing-out nuclear power in the short term was not a realistic option and were thinking that Germany will continue to depend on nuclear power for many years. Only 20% of the respondents believed that Germany could do without nuclear power in the near future. Moreover, the results from the poll showed support from the German public for continued research in the field of nuclear energy, even in a phase-out perspective in the country, in order to keep national expertise and industrial capabilities.

In Japan, there is a general support of future nuclear power deployment even though concerns are expressed regarding safety and risk of accidents.

Recent polls in the United States show an renewed interest in the nuclear energy option in most States but the support to nuclear energy development is the largest in Western States, where energy shortages were most prominent, and the Midwest. A majority of the respondents expressed positive opinions on building new nuclear power plants and renewing the licence of existing nuclear units. Two thirds (66%) of the consulted adults supported building more nuclear power plants, while 87% supported renewal of the license of nuclear energy plants that continue to meet federal safety standards. A majority of the respondents favoured the construction of new nuclear power plants when and where needed, i.e. if the expected demand for electricity could not be met by current power capacity, and close to existing nuclear power plants rather than on new sites.

Aspects of nuclear energy raising most concerns

The main issues raising concerns about nuclear energy are nuclear power plant accidents and radioactive waste disposal. Both concerns are linked with fear of exposure to radioactive emissions and its consequences, i.e. risks of cancer. The ranking of the two issues varies from country to country.

In Finland, most respondents to the poll reviewed expressed concerns about nuclear safety aspects and radioactive waste management issues, but half of them thought that those issues were adequately addressed in the Finnish context. Nearly one third of the respondents stated that the likelihood of a severe nuclear accident resulting in major off-site damage was low enough for them not to be worried. More than two thirds (71%) of respondents considered radioactive waste to be a continuous threat to the life of future generations if not properly managed. However, nearly one third (29%) of them considered that the disposal of radioactive waste in the Finnish bedrock was safe while half of the population was of the opposite opinion.

In France, the poll found that people were more concerned about radioactive waste disposal or reprocessing plants, if those facilities were to be built and operated near them, than about nuclear power plants. According to the poll, no more than a quarter of the French population would be favourable or indifferent to the construction of a nuclear power plant or radioactive waste repository in their neighbourhood.

In Japan, according to the poll reviewed for this study, people are extremely concerned by nuclear safety and severe accident risks associated with the operation of nuclear facilities. Radioactive waste management, including spent fuel reprocessing, raises less concern. Moreover, results from the poll indicated that the Japanese public would like to have access to more comprehensive information on incidents occurring in nuclear power plants and fuel cycle facilities, and on the potential impacts of radioactivity on human health and the environment.

Public participation in decision making

There are only a few opinion polls which include questions directly related to public participation in decision making on nuclear energy policy or nuclear power projects. Generally, responses to such questions are very positive and indicate a willingness of the respondents to be involved more closely in the process of planning and deciding about nuclear energy especially at the local

level (sites of nuclear power plants, fuel cycle facilities and radioactive waste repositories).

According to the Finnish poll reviewed for this study, citizens felt that their chances of participating and influencing the decision making in energy issues were minor. Two-thirds (66%) of people considered that citizens' opinions had not been sufficiently heard in energy solutions. Citizens were also eager to directly participate in and contribute to decision making concerning the disposal of radioactive waste.

Who does the public trust?

According to the polls reviewed, the public in almost all countries believed that the information on nuclear energy provided by professionals was the most credible. In Japan, on the other hand, people thought that newspapers (73% of the respondents among plural choice questions) are the most reliable followed by TV programmes (61%), professionals (44%), local government (11%), magazines (11%), electric company (10%) and plant workers (7%). The government was viewed as having low credibility (only 4% of respondents gave a favourable rating).

A larger majority of the respondents in France thought that nuclear power was important for energy independence, and an even greater majority (76%) expressed confidence in scientists to inform them about nuclear power.

In the Unites States, nuclear professionals and plants workers were considered the best sources of accurate information on nuclear energy issues, with ranking as follows: nuclear scientists/engineers (60% of the respondents among plural choice questions), electric company (51%), plant workers (48%), nuclear regulatory commission (45%), consumer groups (42%), environmental groups (43%), news media (39%), Federal government (28%), anti-nuclear groups (22%).

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7. PRELIMINARY FINDINGS AND RECOMMENDATIONS

Nuclear energy has demonstrated its capabilities to contribute significantly to electricity supply, in particular in OECD countries, and to compete with alternatives. The implementation of nuclear energy projects, however, often raises social concerns about the risks associated with potential release of radioactivity in routine or accidental conditions, radioactive waste management and disposal, and proliferation of nuclear weapons. In democratic societies, those concerns need to be addressed and all stakeholders should be consulted and involved in decision-making processes aiming at consensus on key issues.

The present desk study on society and nuclear energy is the first part of a project undertaken by the NDC that aims at obtaining a better understanding of the interactions between the different stakeholders within the decision-making process related to nuclear energy projects. The main objective of the desk study was to investigate the various issues raised by nuclear energy in the context of modern society through a comprehensive review and analysis of research work and published literature reflecting state-of-the-art knowledge on those topics. This report is mainly intended to serve as a basis for further discussions and in-depth analyses supporting more robust conclusions and recommendations.

The overall assessment of relations between nuclear energy and society shows that a number of factors, either specific to the energy field or related to society as a whole, are influencing the interactions between nuclear energy and the public and eventually the development of alternative energy supply options. The main evolving factors in this regard include consumer behaviour, life circumstances and patterns, urbanisation, electrification, computerisation, and the development of new information and communication technologies (ICTs).

Analysing the relevance of nuclear energy for protecting our natural environment, notably from global climate change, highlights that it is an important option, along with others such as renewable energy sources and efficient use of energy, in sustainable energy strategies for the future. These potential benefits should be an incentive for governments and the industry to address nuclear energy issues challenging its future development, including

social perception of its risks. The evolution of nuclear energy technologies, as well as of the social context, offers opportunities for tackling issues of importance for social acceptance, e.g. nuclear accidents and radioactive waste disposal, and for implementing more efficient information exchange processes between stakeholders, including governmental bodies, regulators, industries and civil society as a whole.

The review of literature and research work on risks provides interesting insights on new approaches to communication with society about nuclear energy risks. Risks constitute an intrinsic and inseparable part of life, and is recognised as such by society, but risk acceptance by the public is generally not objective, but rather operates via perceptions governed by many and widely varying factors. Ultimately, the approval or rejection of a given project that involves the public acceptance of certain risks will depend on a complex trade-off between its perceived risks and benefits. The understanding of the process of risk acceptance and risk-benefit trade-off, as well as of a whole range of factors involved therein, can aid in the development of communication and decision-making processes that reduce the disparity between the technical definition of risk and the lay perception of it.

Traditionally, risks associated with nuclear energy have been estimated using a technical and quantitative approach, called probabilistic risk assessment, and it is recognised that the use of this approach has generally not been well received by the public. The public perception of nuclear energy risks differs markedly from the scientists' view of these risks and is rather high today. The subjective, non-scientific criteria that affect public perception of risk regarding nuclear energy include: the invisibility of radioactivity; the complexity of nuclear technologies; the lack of direct, social control on nuclear projects; the catastrophic aspect of nuclear accidents; the lack of clear need for, and benefit from, nuclear energy in countries where security of electricity supply is of no immediate concern.

The need for greater public participation in scientific and technical decision making is being recognised more and more by the scientific community and it is agreed today that higher levels of public involvement can, and should, be achieved. The field of public involvement in decision making constitutes an active research area and the outcomes from ongoing investigations should contribute to the design and implementation of innovative approaches in the future. The opening-up of new decision-making processes, for example via web-based approaches, may help push public involvement further up the participation ladder.

Ultimately, however, how far the public should be allowed to climb up this ladder should be decided by each country, taking into account the specific national context and the views of stakeholders.

Evaluation of new methods of public involvement should take into consideration both the added qualitative values that public deliberation may bring to a decision, and the potential for increased democratic legitimacy of decisions. Since no single method is perfect, there is often a trade-off to be made between the deliberative dimension some methods offer and the representative capacity of others. Specific findings from past experience include that a high degree of trust and transparency needs to be established and maintained within the public realm to give public participatory processes legitimacy and accountability.

Recognising that some important aspects of decision making in the nuclear sector are undertaken at the political level, the direct contribution from decision-making research to progress in the nuclear energy field is arguably limited. Nevertheless, two particular perspectives are identified that are of real significance for those decision makers who look to gain a better understanding of interactions between society and the nuclear energy sector in terms of how decisions are reached. First, formal processes that are based on ideas developed in the decision-research literature, e.g. following a multi-criteria decision support perspective, can usefully support the complex decisions often encountered in the nuclear energy sector. Indeed, the absence of such support is very likely to induce sub-optimal decision making in many circumstances. Second, it is of critical importance to bring a full understanding of intuitive judgements vis-à-vis decision processes into play, even in cases where structured support methods are applied.

Analysing data from public opinion surveys already carried out in member countries has proven to be difficult owing to differences in scope, coverage and methods adopted in each survey. Nevertheless, two main features of public opinion and concerns about nuclear energy issues can be identified in the surveys reviewed for the present study. First, in several cases, public attitudes towards nuclear energy do not seem to be reflected in the national energy policy pursued by governments, e.g. phase-out or moratorium. This may result from the intrinsic inertia of large technological and political systems, but it may also indicate that public involvement in policy and decision making concerning the nuclear energy sector is insufficient. Second, it seems that people are interested in having access to more information on nuclear energy. Recognising that knowledge is important to allow the public to understand better nuclear energy issues, this declared interest offers opportunities to eventually enhance confidence in nuclear energy through better information.

Another important observation drawn from opinion polls is that access to comprehensive information may enhance public trust in the bodies – such as governments and industries – that provide this information, especially if they do so in an open and transparent way. Building trust through information sharing and effective communication is essential for further use and development of nuclear

energy. In modern democratic countries, civil society is likely to play an increasingly important role in all decision-making processes and accordingly nuclear energy policy is likely to be increasingly influenced by public opinion. In this context, carrying out and thoroughly analysing public opinion polls on major aspects of nuclear energy constitute an integral part of nuclear energy policy making.

This desk study provides only preliminary findings that call for more in depth review and analysis of key issues. The importance of risk perception and communication is highlighted by the literature surveyed and presented within this report. Additional work in this field would be relevant to facilitate the dialogue between experts, policy makers and civil society about nuclear energy issues, eventually leading to more effective decision-making processes.

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Society and Nuclear Energy: Towards a Better Understanding

While signs of a possible nuclear energy renaissance are visible worldwide, it is highly important to understand better the views of civil society on nuclear technologies, how their risks are perceived, and how to establish effective communication between all stakeholders aiming at enhancing consensus building prior to decision making.

This report is based upon an in-depth analysis of research work and published literature on risk perception and communication, public participation in policy and decision making and the evolution of public opinion on nuclear energy. It will be of interest to policy makers, governmental agencies and industry. Additionally, members of civil society and various stakeholders eager to learn more about social issues related to the development of nuclear energy will find relevant information in this report.

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OECD Nuclear Energy Agency
Le Seine Saint-Germain – 12, boulevard des Îles
F-92130 Issy-les-Moulineaux, France
Tel.: +33 (0)1 45 24 10 15 – Fax: +33 (0)1 45 24 11 10
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