

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900

Open access books available

185,000

International authors and editors

200M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Strategic Environmental Considerations of Nuclear Power

Branko Kontić
Jožef Stefan Institute
Slovenia

1. Introduction

The key topics of this chapter are i) comparative evaluation of various energy options, and ii) radioactive waste disposal. Both are treated from the strategic planning and assessment points of view and are supported by a discussion of multi-objective decision-making. Environmental considerations are foremost. The discussion is focused on the uppermost level of societal energy planning, and attempts to answer strategic questions concerned with the comparative evaluation of various energy options and waste disposal. It is guided by a number of questions as illustrated in Table 1. The Table also indicates in which sub-chapter a certain, more specific discussion can be found.

The author is a natural scientist, experienced in research and preparation of different types of environmental impact and risk assessments. At the present time – January 2012 - after more than 30 years of practice in the field he is astonished by the increasing inefficiency of formal guidance on evaluation of environmental impacts. He wonders why is this so and is especially disappointed when seeing that even the highest administrative level EU institutions, the DG Environment and DG Regional Policy, do not succeed in implementing the guides on performing strategic environmental assessments. For example, the DG Regional Policy and Cohesion provided a guide for the ex-ante evaluation of the environmental impact of regional development programmes in 1999 (EC, 1999) as complementary to the Handbook on Environmental Assessment of Regional Development Plans and EU Structural Fund Programmes (EC, 1998). These were a kind of predecessor of the EU Directive 2001/42/EC (usually referred to as the strategic environmental assessment - SEA Directive). Despite the fact that the guides clearly stress the importance of establishing an interactive relationship between evaluation and planning – the objective of the integration is to improve and strengthen the final quality of the plan or programme under preparation – more than 10 years afterwards Member States fail to follow them and report on a number of difficulties in SEA implementation (EC, 2009). The most important deficiency in the current practice of SEA in certain EU countries is still the approval/permitting context of the use of SEA instead of the planning context and optimisation of plans, and the mixed use (misuse) of project level environmental impact assessment - EIA and SEA. SEA is very often used for the evaluation of specific projects, while EIA is used at higher, i.e. strategic, levels, sometimes even for the evaluation of sustainability of plans and programmes (Kontić & Kontić, 2011). This situation stimulated the author to prepare the present condensed overview

of research and consultancy results on strategic considerations of nuclear power. His aim is that this will contribute to the desired change of implementation of strategic evaluation in the area of energy production and elsewhere.

Comparative information about the environmental impacts of various energy systems can assist in the evaluation of energy options and consequent decision making. Over the last thirty years a number of studies have attempted to quantify such impacts for a wide range of energy sources. These estimations have taken different approaches, from impacts of fuel acquisition through to waste disposal (IAEA, 2000). Recent major studies have been completed and new studies begun in which nuclear power is either supported – justification through e.g. climate change issues or low-carbon society – or criticised – justification through e.g. accidents at Chernobyl and Fukushima, or waste related issues. The results of the studies provide useful insights and help to promote further studies of impacts for many technologies and sites. However, the strategic level of these considerations still remains less well covered and a number of questions are still unanswered. This chapter is aimed as a contribution to filling these gaps.

Related to the radioactive waste issue, the siting of a disposal facility or final repository is a task with unique traits that are clearly associated with changes in the surrounding world. A number of questions can be posed regarding how ongoing and future changes in technology, views, politics and practices in other parts of the world, concerning e.g. energy supply, nuclear power and nuclear waste, may affect national decisions regarding the approach and decisions involved in successful and safe disposal of the waste. National trends in politics, economy and opinion also influence events and views, locally and nationally (SKB, 2011). The decision-making process has to fulfil certain democratic expectations and criteria: openness, transparency, participation. So far, known and applied approaches have not been efficient or effective in solving the primary issue of participatory decision-making in this area, i.e. proper, fair and balanced consideration of specific priorities and interests. Neither weight assignment, as a representative method rooted in (expert) opinion and value judgements, nor methods based on statistics and probability theory (applicable for measurable attributes) have proved successful for this purpose. Maybe 'approval voting' (Laukkanen et al., 2002) is the closest to what is widely understood as participative/democratic decision making. It appears, on the other hand, that a continuous engagement process, sound and consistent, scientifically supported and respected by all involved parties, which deals adequately with uncertainties related to long-term predictions/evaluations – as applied in Finland and Sweden – can provide satisfactory results (SKB, 2011). The approach applied in Slovenia for identifying and approving a site for a low and intermediate level radioactive waste disposal facility could also be seen as being successful, and is presented in more detail in Section 3. In summary, it builds on social acceptance of predictive uncertainty based on so-called "local partnership" i.e. the community is actively involved in the siting process and has a right of *veto*, together with a comprehensive investigation of the perceptions of the types of consequences rather than the likelihood of their occurrence. The underlying basis of the approach is that it is more promising to investigate which consequences of a certain alternative are more likely to be accepted by society than how likely these consequences are to occur. Thus, as many feasible alternatives as possible should be evaluated, so that the parties involved can express their preferences rather than just "yes/no", or "accept/reject" responses. This is clearly in line with the basic philosophy of SEA and strategic considerations of nuclear power.

Questions/Issues	Comments/Specification
What are the energy needs? What are the energy issues? What are the strategic energy goals?	The questions are inter-connected. At the country level these questions need to be answered in a solid, transparent and inter-disciplinary way. It is the responsibility of politics to ensure full and proper involvement of societal* planners in answering these questions. In the process of answering the questions it is necessary to know where to get information/ data and who to involve; the answers should be reliable, valid, and trustworthy. See subchapter 2.1.
Spatial planning and strategic environmental assessment; Territorial impact assessment	Energy policy should be integrated with spatial planning procedures at high planning levels. Planning and strategic environmental impact evaluations should be integrated. See subchapter 2.1.
What are the expected outcomes of strategic considerations? What forms of auditing have to be implemented to achieve trust in the answers about strategic policy? Who are the decision-makers?	Early involvement of interested parties, early input by decision-makers with their guiding elements, and clarification/ agreement on representation issues associated with different social groups should be resolved and implemented in the process of creating a trustworthy energy policy. See subchapter 2.1.
Why choose nuclear technology? Is nuclear power a good choice?	Solid and transparent comparative assessment of the various options should first be made on the strategic level, i.e. without detailed information on environmental status at potential sites for different options. This requires proper comparative environmental indicators. For example, indicators on specific air emission from different technologies (e.g., radioactivity from NPPs, and CO ₂ from coal fired power plants) should not be directly used for comparison. Rather, common consequences in the environment, which these emissions may cause, should be the subject of comparison. See subchapters 2.1 and 2.2.
Which uncertainties have to be considered when deciding about energy options? Is trustworthiness of planners and scientists just another imperative? How to distinguish between facts and values? What is the role and credibility of regulators in the process of approving long-term predictions of environmental and health impacts?	At least the sources and types of uncertainty should be clearly explained when quantification is not feasible (e.g., long-term future predictions cannot be checked/ verified at the present time, so performance assessment results of a particular radioactive waste repository for the next million years cannot be quantified, either in terms of environmental or societal changes). Scientific truth related to siting of the repository should be tested in the communication process at international, regional and local levels. See subchapters 3.1, 3.2, and 3.3.

* By societal planning is here meant an integration of all sectoral planning, including environmental.

Table 1. Questions and issues in strategic considerations of nuclear power

2. Comparative evaluation of environmental impacts of various energy systems

2.1 Energy planning, assessment and decision-making

In a very general terms, when one gets involved in planning it is strongly recommended to consult the theoretical background to the topic and its integration with strategic evaluation. As an initial and philosophical reading one may choose Nigel Taylor's article Planning theory and the philosophy of planning (Taylor, 1980) where the author provides an overview and explanation of the relationship between values and facts and the logical distinction that can be made (and thus between ethics and knowledge). The sections on Ethics and Planning, and Knowledge and Planning, clearly explain the reasoning necessary when making strategic choices related to development plans.

2.1.1 Key parties involved

The evolution towards a more comprehensive approach to electricity system planning emerged from a broader recognition of the need to identify the broad social responsibility of the power sector. The concept of social responsibility covers a number of issues ranging from local employment to rational exploitation of national resources. It implies a comprehensive analysis of natural resource requirements and social, health and environmental impacts arising at all steps of the energy chains constituting the electricity generation system (IAEA, 2000).

Integration of the power system analysis and planning process within the social and economic context can be considered as a shift from minimising costs (i.e. direct cost of electricity production) to maximising effectiveness. The concept of maximising effectiveness should be understood, in a broad sense, as an attempt to find solutions optimised from the view point of society as a whole. In this context, the planning process is aimed at seeking the preferred supply and demand side options and the strategies for solving present problems in the power sector (e.g. supply shortages, high costs with unclear externalities, non-compliance with environmental policy goals and regulations). This, at the same time as addressing various objectives of the electricity utilities, integrates the various actors in the energy and other economic sectors and, more generally, all interested and affected parties (IAPs) (IAEA, 1999; IAEA, 2000).

This shift in emphasis requires a comprehensive consideration of the overall objectives underlying the development of the power sector and of the parameters (attributes), data and assumptions that have to be taken into account in analysing alternative technologies for electricity production, and the electricity system as a whole. In particular, the power sector has to be analysed as one part within the overall economic and social context (URS, 2010).

In recent years, the traditional utility oriented decision making process has changed to involve a larger number of actors. Figure 1 shows a schematic diagram of the respective roles and responsibilities of the three main groups of actors involved in the overall planning, assessment and decision-making process. Decision makers have the key responsibility for identifying the problems needing solution and for choosing from among the possible solutions derived by decision support studies, according to their own values and priorities, as well as the political and social context. Interested and affected parties have an important

role to play in the overall process, and their viewpoints and concerns have to be recognised and taken into account, insofar as is feasible, at each step, starting at the very beginning. The role of electricity analysts/planners is to formulate the decision maker's problems in an analytical framework and to derive alternative possible solutions, taking into account relevant constraints (e.g. emission limits, public health goals, land-use interests) imposed by regulators and concerns expressed by IAPs (IAEA, 2000).

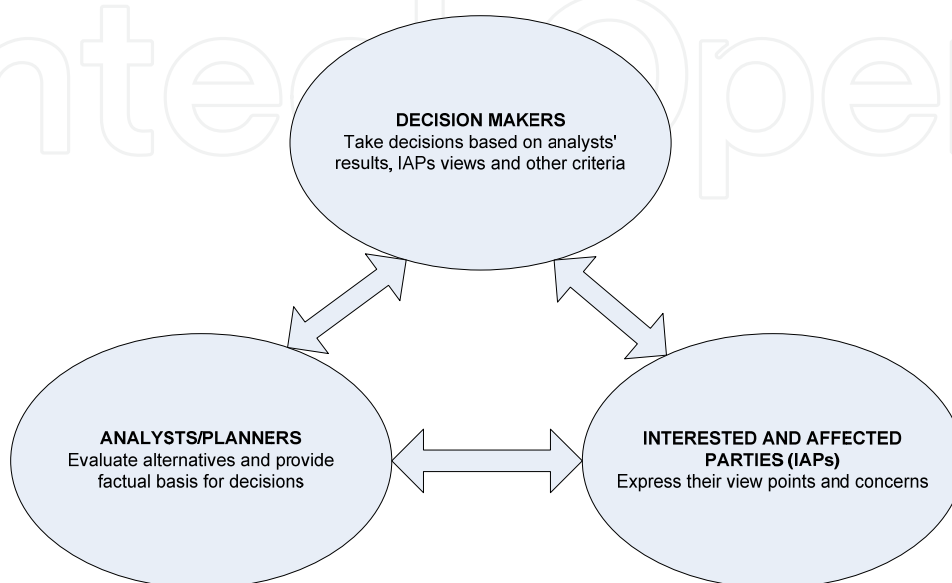


Fig. 1. Schematic diagram of interactions in the decision making process (IAEA, 2000)

2.1.2 Planning and strategic assessment

The production and consumption of electricity lead to environmental impacts which must be considered in making decisions on the way in which to develop energy systems and energy policy. The key to moving towards rational energy development lies in finding the 'balance' between the environmental, economic and social goals of society and integrating them at the earliest stages of project planning, programme development and policy making. The environmental consequences of energy production and use must be known in order to manage and choose energy products and services. The requirements for information in support of corporate and/or government planning and decision making are changing, there being a clear emergence of concerns for environmental accountability. Thus, there is a need to integrate the environment more effectively into all aspects of energy planning and decision making, in order to make current decisions environmentally prudent, economically efficient and socially equitable, both now and for the future. Assessing environmental impacts associated with different energy systems through the use of a framework which facilitates comparison will permit consistent and transparent evaluation of these energy alternatives.

Tiering of environmental evaluation

Appraising sustainability

Sustainability appraisal (SA) has recently emerged as a policy tool whose fundamental purpose is to direct planning and decision-making towards sustainability. Its foundations

lie in well-established practices such as strategic environmental assessment (SEA), applied to policies, plans and programmes, and in project environmental impact assessment (EIA). The distinguishing feature of sustainability appraisal, when compared with others, e.g. SEA, is that the concept of sustainability, not just the environment, lies at its core. However, as explained below, comprehensive SEAs also deal with all three components – environment, economy and society – in a balanced way. No matter which type of assessment is applied at the highest planning level, either SA or SEA, its aim is to provide answers in a comparative manner and to assist in the process of identifying the most suitable alternative, e.g. energy option.

Strategic environmental assessment

SEA is a systematic process for evaluating the environmental consequences and for identifying the adverse effects of emerging environmental and/or health risks of a proposed policy, plan or programme. This is necessary in order to ensure that they are fully included and appropriately addressed at the earliest appropriate stage of decision making, on a par with economic and social considerations. As such, SEA may also include social and economic considerations. Due to these features SEA is often interchanged with SA, however, some countries and practitioners make SEA more narrow in its scope and almost purely environment oriented. Figure 2 schematically shows different combinations of depth and scope of the assessment.

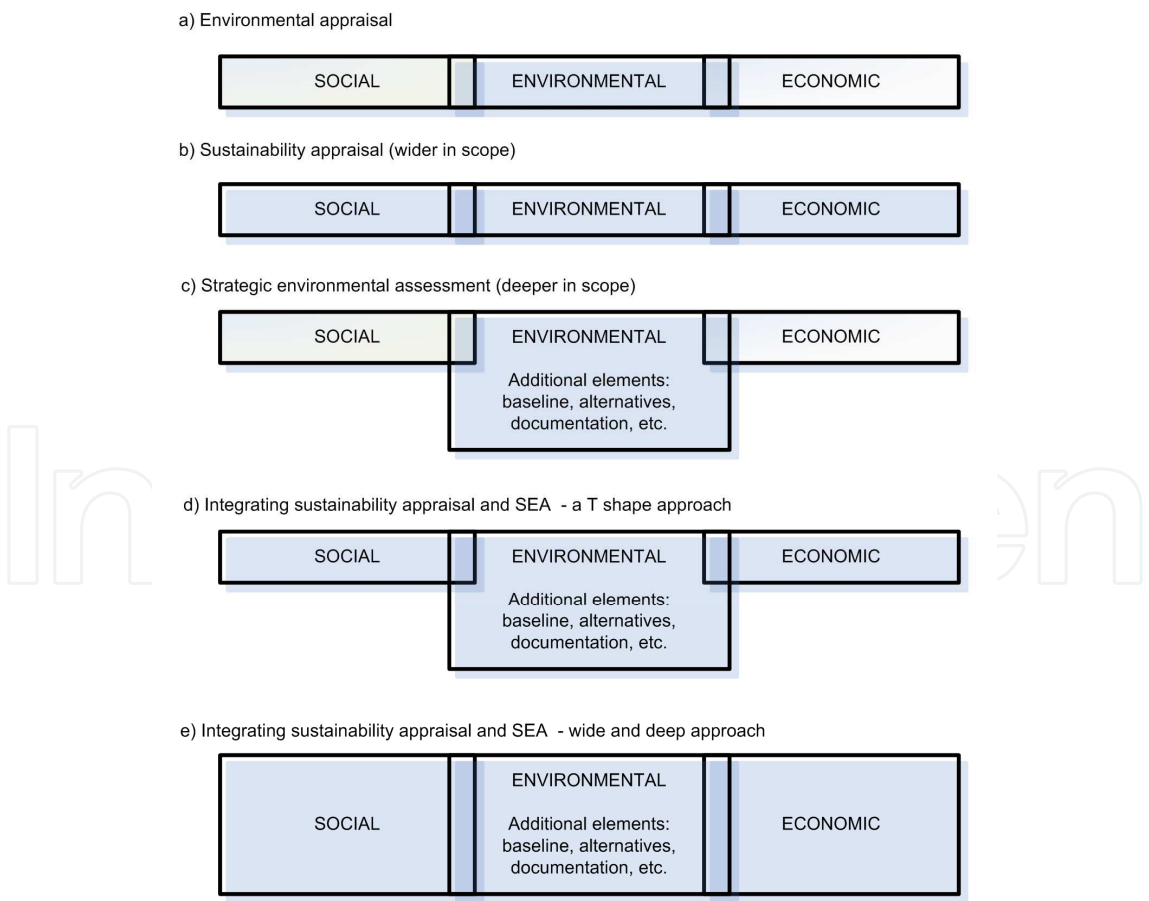


Fig. 2. Evolution from environmental appraisal to comprehensive/integrative SEA (Therivel 2005)

SEA deals with impacts that are difficult to consider at the project level. It deals with cumulative and synergistic impacts of technologies or multiple projects. This is very difficult to address by individual project oriented EIAs.

SEA promotes a better consideration of alternatives and affects the decision-making process at a stage where more alternatives are available for consideration. The following characteristics of SEA should be recognised (Therivel, 2005):

1. SEA is a tool for improving the strategic action, not a post-hoc snapshot;
2. In order to fit into the timescale and resources of the decision-making process, SEA should focus on key environmental/sustainability constraints, thresholds and limits at the appropriate plan-making level. It should not aim to be as detailed as a project oriented environmental impact assessment;
3. SEA aims to identify the best alternative for the development and implementation of policies, plans and programmes;
4. SEA aims to minimize negative impacts, optimize positive ones, and to compensate for the loss of valuable (environmental and other) features and benefits.

Project related environmental impact assessment (EIA)

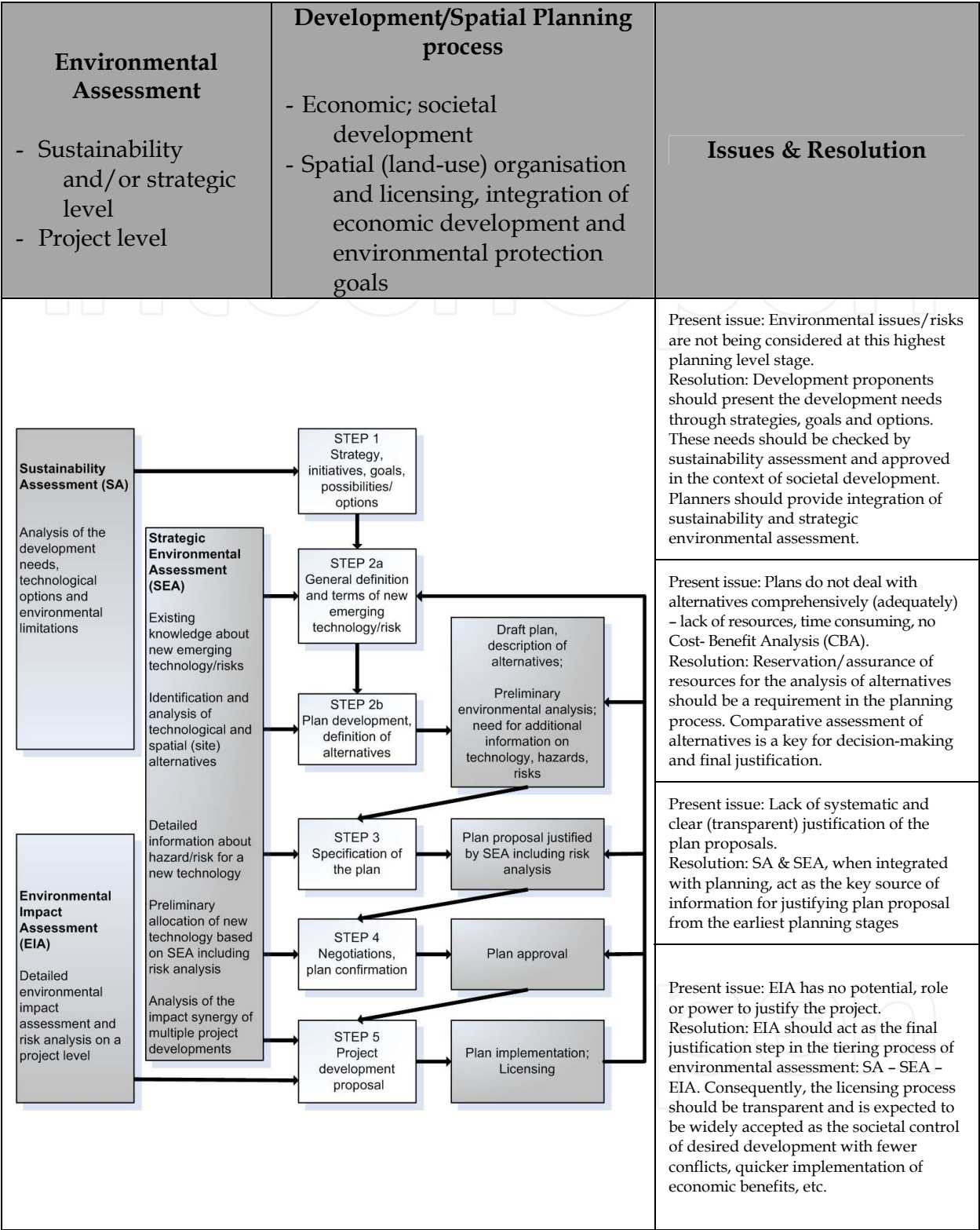
EIA is the selected technology and location linked consideration. Environmental assessment is specific, concrete, and deep. The endpoint is to determine clearly the environmental changes in terms of their scope, intensity and tolerability. Risks are assessed quantitatively. Very specific indicators of environmental quality may be applied.

Integration of strategic planning and environmental evaluation

Figure 3 provides a synthesis of the desired integration between strategic planning and tiering environmental evaluations. A brief overview of present issues and their possible resolution at different planning stages is also given. One should not overlook the importance of a loop from the fifth planning step (Plan implementation; Licensing) back to the step 2a informing all planning steps between success and issues in the plan implementation. This loop actually acts as a special form of historical monitoring of the plan implementation.

Comparative evaluation approach and its indicators

Multi-objective analysis (MOA) is aimed at facilitating comprehensive and consistent consideration, comparison and trade-offs of economic (financial), supply security, social, health and environmental attributes of selected alternative energy options or systems (could also be technologies for electricity production). These technologies are usually classified as thermal and non-thermal, or renewable and non-renewable, and include nuclear, coal, natural gas, biomass, hydro, PV-Photo Voltaic, and wind systems. MOA is expected to assist in the systematic evaluation of options according to multiple objectives/criteria which are different and which may not be measured on an interval (or even ordinal) scale. It should be understood that MOA is not primarily a method that can be used to derive impacts, but rather a method that places different types of impact on a comparable basis and facilitates comparisons between impacts originally estimated and expressed in different units (IAEA, 2000).



Note: The term "new emerging technology/risk" relates to any new development having a potential for causing environmental damage, e.g. a new generation of nuclear reactors, hydrogen based fuel technology, nano technology, etc.

Fig. 3. A schematic presentation of a possible integration of the development and spatial/land-use planning process with environmental evaluations (SA, SEA, EIA)

The main objectives of MOA are:

- to provide quantitative information where it is difficult to quantify the impacts directly;
- to display risk–benefit trade-offs that exist between different impact indicators;
- to facilitate comparisons and trade-offs;
- to facilitate understanding of the ‘values’ that need to be placed on different attributes.

The impact of each option under consideration should be represented using the units of measurement appropriate for each indicator or attribute. For example, impact indicators could be:

- The proportion of area utilized in the area (e.g. as a measure of land use impacts associated with each option referring to shares of existing and planned land-use);
- Health determinants affected/changed due to implementation of the alternative energy option.

Table 2 indicates a set of aggregated indicators; these need to be developed further into measurable (possibly quantifiable) sub-indicators, so as to enable clear, verifiable, reproducible, and transparent evaluation. How this could be done in a comprehensive and transparent manner shows the example of Eurelectric RESAP - Renewables Action Plan (Eurelectric, 2011); the WG Environmental Management and Economics of the Eurelectric RESAP was tasked with an evaluation, based on existing literature – 296 selected worldwide studies - of the sustainability of renewable energy sources (RES) and other technologies over their whole life cycle (IPCC, 2011). The quantitative indicators applied in comparative evaluation were, e.g., carbon footprint, health impacts, water use, land use, biodiversity, raw materials, energy payback, etc. No matter the approach of selecting the indicators, caution should be exercised to ensure that the sub-indicators are chosen on the basis of:

- Relevance: indicators should reflect the overall objectives of the study;
- Directionality: indicators must be defined in a manner that ensures that their magnitude can be assessed and interpreted. This can be accomplished by specifying indicator measurement in terms of maximizing or minimizing, increasing or maintaining, etc.;
- Measurability: it should be possible to measure quantitatively or estimate directional impacts of each alternative on each indicator, in the unit of measurement that is appropriate for the indicator. Directionality and measurability together determine interpretability, i.e. they permit an interpretation of impacts as being good/bad or better/worse on each indicator;
- Manageability: in order to make assessments comprehensible and to facilitate effective comparison, the number of sub-indicators should not be too large.

Once the impact analyses have been consolidated, all the data should be expressed in a common metric, or ‘standardized’, so that the indicators can be compared and assessed. For example, impact indicators can be presented on an interval scale (e.g. from 0 to 1). The scale would indicate the relative effect of each fuel chain option being considered, on the basis of the relative magnitude of the impact indicator.

The process can be standardized as follows (adapted from Canter & Hill, 1979 and combined with IAEA, 2000):

Main (aggregated) indicators	Goals/objectives as a basis for specification of sub-indicators and development of the evaluation criteria
Cost/Value	Development of competitive (least cost) electricity production
Supply Reliability	The energy payback ratio
Economic/Technological Advancement	Development of an electricity system expansion plan that minimises greenhouse gas emission
Risk/Uncertainty Management	Enhancement of the welfare of local communities; growth of social capital across region
Environmental and Health Impacts	Protection and improvement of the health of all residents and workers (good access to health care, reduced health inequalities, affordability of safe and quality nutrition, availability of recreation zones/infrastructure, nursing/work/social inclusion for elderly people, clean and healthy environment, safe urban areas, etc.)
Welfare of local and regional communities	Changes/improvements in regional and local employment Improvement of economic benefit to the community (to reduce disparities in income; access to jobs, housing, and services between areas within the region and between segments of the population; access to better and effective education; energy efficiency; etc.) Maintenance of high and stable levels of economic growth (good accessibility to business within the region, stronger linkages between firms and the development of specialism within area, local strengths and economic value locally, emergence of new and high technology sectors and innovations, etc.). Effective protection of the environment (maintenance and enhancement of the quality and distinctiveness of the landscape; making towns more attractive places to live in; maintenance and improvement of the quality of air, ground and river water; reduced contribution to climate change (greenhouse gases); moving up through the waste management hierarchy; prudent use of resources – to reduce consumption of undeveloped land, natural resources, greenfield sites; to reduce need to travel; to apply reasonable, long-term land-use planning considering open space; improvement of resource efficiency; etc.)

Note on sustainable development: Sustainable development *does not mean* having less economic growth. On the contrary, a healthy economy is better able to generate the resources for environmental improvement and protection, as well as social welfare. It also does not mean that every aspect of the present environment should be preserved at all cost (*extremism, fundamentalism*). What it requires is that decisions throughout society are taken with proper regard to their environmental impact and implications for wide social interests. Sustainable development *does mean* taking responsibility for policies and actions. Decisions by the government or the public must be based on the best possible scientific information and analysis of risk, and a responsible attitude towards community welfare. When there is uncertainty and the consequences of a decision are potentially serious, precautionary decisions are desirable (see Hansson, 2011 for further discussion on applying the precautionary principle). Particular care must be taken where effects may be irreversible. Cost implications should be communicated clearly to the people responsible.

Table 2. A list of main indicators to be applied in comparative multi-objective assessment

- a. For each indicator, the analyst should identify the best value (e.g. highest contribution to employment) and the worst value (least contribution to employment) from the alternatives under consideration.
- b. Then, the impact scale should be arranged on a horizontal axis from the best value (at the origin on the scale) to the worst value (at the extreme of the scale). The scale will depend on the units of measurement used in the impact assessment for each indicator.
- c. Then, the standardized values of the impact indicators should be represented on the vertical axis, the same for all indicators and ranging from 0 to 1.

Finally, an indicator value of 1 should be assigned to the best option and 0 to the worst. The other options are then located according to their impact values on the line joining the best and worst.

Once the impact data are standardized, the following three methods could be used for the aggregation of results (IAEA, 2000; Kontić et al., 2006):

- Weighting; weight should be assigned to each indicator on the basis of its relative importance, for instance in a comparison of human health, global environmental impacts and land occupation (land-use impacts). Sensitivity analysis of the weighting should be performed in terms of investigating the difference in final comparative assessment results due to assignment of different weight values to a particular indicator (at least three justified variations should be considered); the final amalgamation method can be weight summation.
- Aggregation rules; based on standardization of the indicator's values, and a tree structure of the whole set of indicators where a root of the tree represents the ultimate aggregated value; pairs or sets of multiple indicators should be aggregated and evaluated by means of the »if-then« approach. In this way the aggregation rules should be developed as an alternative to weighting. A final score is derived by comparing aggregated values at the tree root for the treated alternatives. This approach is described in detail in (Bohanec, 2003) while an example of a decision tree specifying evaluation indicators is presented in Figure 4.
- Trade-offs; the final product of the analysis should be presented as a description of trade-offs in either tabular or graphical form. Goal programming can employ the amalgamation method which ranks the alternatives on the basis of the deviation from a goal or target that analysts (decision makers) would like to see achieved: the less the deviation, the closer to the goal, and thus the higher the alternative is ranked.

The analysts' view on the three methods and results achieved should be a part of the conclusions.

Presentation of the evaluation results

The analytical study should provide a systematic comparative assessment of the consequences (costs, benefits, impacts and risks) of alternative energy options (technologies). For decision-making purposes, these results need to be evaluated and presented in a coherent way. The evaluation and presentation of the results should focus on pointing out the main findings and conclusions that could support decision taking.

In order to assist decision makers effectively, analysts should present their results in a transparent manner (no "black boxes"), focusing on the verifiable results and their interpretations. In particular: input data and assumptions should be specified clearly and the boundaries and limits of the study should be indicated; comparison of alternatives should be based upon indicators that have been estimated quantitatively and qualitatively.

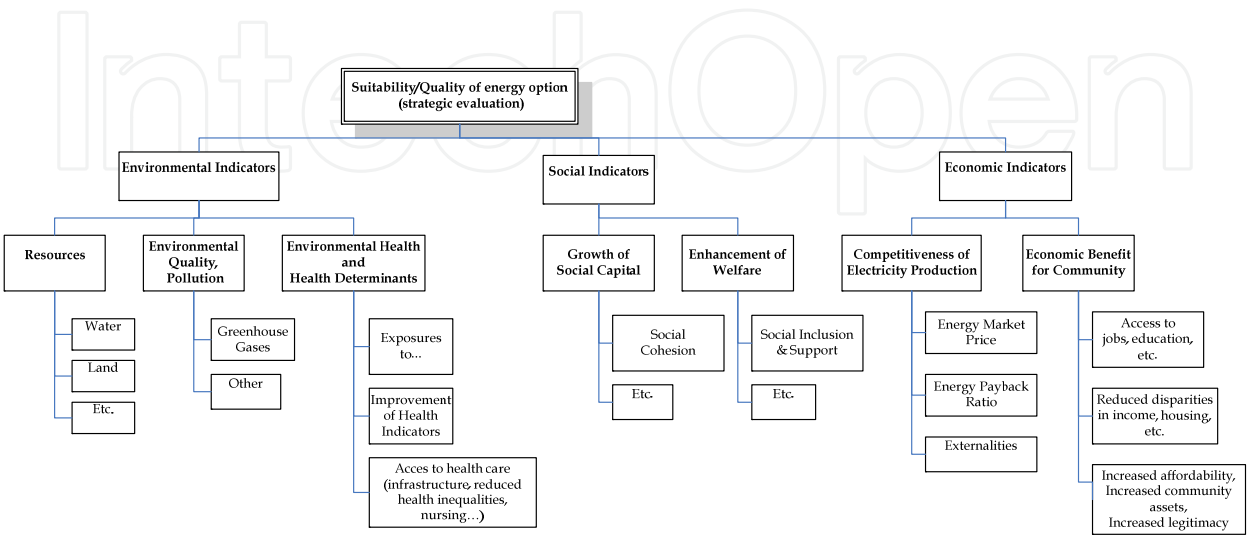


Fig. 4. A set of comparative assessment indicators for different energy options at the strategic evaluation level. The set is organised in a (decision) tree structure.

In general, the presentation of the results has to be adapted to the target audience of the study. The primary audience will be decision makers. However, in most cases, the study will also be disseminated to, and used by, interested and affected parties, e.g. local communities or NGOs. In both cases, the audience has not the same experience and knowledge on technical and economic issues as do the analysts. Therefore, results should be presented clearly and concisely, pointing out the main findings and outcomes.

2.2 Multi-objective decision making

Multi-objective decision making builds on previous multi-objective (sometimes called multi-attribute) valuation of the alternatives. Because the different ways to solve the problem tend to be mutually exclusive, the selection of the "best" option requires the formulation of trade-offs among the different attributes used to evaluate the performance of the several possible alternatives. Such trade-offs require a multi-objective analysis (see above) in order to assess and compare the relative merits of the alternatives. In practice, a multi-objective analysis usually does not yield a single optimal alternative. Therefore, the choice of the "best" solution requires that the decision maker's preferences and value trade-offs among conflicting objectives be clearly articulated and made explicit in the selection process. A vast number of publications on multi-attribute decision making is available from which one can extract useful information and guidance on how to perform such decision modelling. The following selection may serve as an introductory reading to the comprehensive overview of approaches, methods and tools for different multi-objective decision applications (Bohanec & Rajkovič, 1999; Bohanec , 2003; Munda et. al., 1995).

3. Radioactive waste disposal

3.1 Perception of radioactive waste disposal issues

The recent international perspective can be found in the report "Resource or waste? The politics surrounding the management of spent nuclear fuel in Finland, Germany, Russia and Japan" (SKB, 2011). A clear historical divide can be discerned between countries that decided to reprocess spent nuclear fuel and those that chose final disposal. Three of the countries mentioned – Japan and Russia and, in an earlier phase, Germany, have considered spent nuclear fuel as a resource rather than as waste, and for that reason invested in reprocessing. The report provides an account of how and why these countries chose different alternatives; why, despite a common basic approach, they gradually came to aim at completely different strategies and methods for spent nuclear fuel management. Today Germany has totally abandoned its previous reprocessing strategy, Russia has maintained its strategy, but also steered certain operations toward direct disposal, and Japan has recently completed a major industrial reprocessing facility. The issue of final disposal is, however, far from solved in Germany and Japan. In order to understand why different countries have chosen one alternative over another, and how a strategy changed over time, the authors chose to elaborate on eight key dimensions. Five of these relate to nuclear power issues, such as whether or not a country produces nuclear weapons, has an expanding or stagnating nuclear power sector, weak or strong competence in the field of nuclear energy, good or poor prerequisites for a final repository, and whether or not it has domestic uranium resources. Three other dimensions cover political characteristics, i.e. whether or not the country had or has a strong or weak anti-nuclear movement, whether it is a democracy or a dictatorship, and whether or not it is characterized by strong or weak local political power. The latter aspect is seen as essential to issues of local acceptance of a spent nuclear fuel repository. The reasons behind different choices appear to be the military use of spent nuclear fuel and the absence of democratic discussion (Russia), consensual political decision-making (Finland), and situations of strong political opposition and local disputes (Germany and Japan).

In the project "Nuclear waste: From an Energy Resource to a Disposal Problem" (SKB, 2011) Jonas Anshelm analyzed the nuclear waste debate since the 1950s, including issues of risk, responsibility, design of a final repository and safety of the technology. The author points to the importance of elucidating the different kinds of answers that have been given concerning these issues in different time periods. The challenge is to understand how changing technological, political, economic and scientific circumstances have influenced perceptions and debates. Such clarification can broaden the perspective and facilitate an understanding of the complexity of the issue. The project observes shifts in meaning and public opinion changes regarding central aspects on the nature of nuclear waste – as a resource or as a waste, and the characteristics of the waste – as well as of its associated risks. Likewise, issues of who has responsibility for the final repository, what should be considered scientific facts concerning bedrock characteristics, and the sustainability of the technological solutions, have been subjected to controversy throughout the period. It is striking, Anshelm notes, that central actors have been both utterly confident in their opinions and able to assume totally different points of view in new situations. This characterization applies to both proponents and opponents of nuclear

power. In summary, this contribution illustrates that what is perceived to be true, valid, correct, morally right, and rational with respect to the debated issue has recurrently been subject to renegotiation and change during the past half-century. This has resulted in a number of serious conflicts since the 1970s. The issue has currently reached a level of stabilization and does not exemplify a strong national or local controversy. It is, however, reasonable to assume that current views on what is true and right regarding the nuclear waste issue – on which there is some consensus today – will, in the future, also be subjected to renegotiations in the light of scientific, technological, economic and political reorientations. This already appears to have been triggered in a number of countries, e.g. Germany, Japan, Slovenia, by the consequences from the damaged NPP Fukushima I after the quake and tsunami in March 2011. It could be viewed that this accident encouraged the German government to announce that it will bring forward the closure of its nuclear power stations to 2022, 14 years earlier than originally planned, while Japan considers a review of plans for construction of new NPPs, just like Slovenia in its new National Energy Programme currently under debate.

3.2 Waste disposal siting

Radioactive waste should be disposed of in a way that guarantees its isolation from the biosphere. The release of potentially harmful substances - radionuclides - must be prevented or limited to levels that do not harm human health or the environment (IAEA, 1994). In this context, the issue of a proper siting process gains importance, especially in terms of selecting a site that has geological, hydrological, seismic, morphological and other characteristics that would not contribute to the release of radioactivity from a repository and subsequent exposure of the population. The site selection process is therefore a critical step in the overall site acquisition process. Countries are seeking their own ways on how to achieve these goals. As regard Slovenia it may be seen as a successful example concerning low and intermediate level waste (LILW) disposal. However, a strategy for the management of spent nuclear fuel and high level waste (HLW) is still under consideration.

The benefits of strategic environmental considerations in the process of siting a repository for LILW are clearly presented in Dermol & Kontić, 2011. The benefits have been explored by analyzing differences between the two site selection processes. One is a so-called official site selection process, which was implemented by the Agency for radwaste management (ARAO); the other is an optimization process suggested by experts working in the area of environmental impact assessment (EIA) and land use (spatial) planning. The criteria on which comparison of the results of the two site selection processes has been based are spatial organization, environmental impact, safety in terms of potential exposure of the population to radioactivity released from the repository, and feasibility of the repository from the technical, financial/economic and social points of view (the latter relates to consent by the local community for siting the repository). The site selection processes have been compared with the support of the multi-objective decision expert system named DEX –Decision EXpert (Bohanec & Rajkovič, 1999). The results of the comparison indicate that the sites selected by ARAO meet fewer suitability criteria than those identified by applying strategic environmental considerations in the framework of the optimization process. This result stands when taking into account spatial, environmental, safety and technical feasibility

points of view. Acceptability of a site by a local community could not have been tested, since the formal site selection process had not yet been concluded at that time. Now the consent has been granted and ARAO is about to start construction of the repository in 2012. This approach to siting and comparison of the two site selection processes may serve as an example of transparent and inclusive - the local partnership has been established - way of dealing with radioactive waste disposal.

3.3 Uncertainties

3.3.1 The time perspective of nuclear waste

The most discussed aspect of nuclear waste is its longevity. Previously nuclear waste was the only issue for social decision-making that was widely discussed in very long time perspectives. Today climate change is discussed in such long time perspectives, and we also have a general discussion on sustainable development that does not have any time limits (Hansson, 2011). Hansson further says that discussions on decisions related to very long time perspectives include the issue of *how* to evaluate outcomes in the future. For example, is the value of a human life similar or dissimilar if it relates to assessing a final repository in e.g. 10,000 years hence, or in our time? And how should uncertain outcomes be evaluated? We seldom know about the consequences, in a hundred year perspective, of a decision taken today. This uncertainty has often resulted in not caring for the long-term consequences of the actions. The nuclear waste issue has become a pioneering case in the sense that uncertainties have not hindered us from considering long-term consequences seriously. Hansson's concluding observations are that it is not the uncertainty *per se* that has resulted in the high attention and controversy regarding future effects of a nuclear waste repository, but rather the combination of certainty in specific areas (e.g. radioactive decay over time, etc.) and uncertainty in other areas (e.g. future generations' knowledge, intentions, etc.). Finally Hansson notes that the International Climate Panel (IPCC) focuses on a time perspective of around 100 years and utilizes a kind of "trimmed discounting" in the work. He concludes that this is rather unprincipled reasoning, and suggests that much would be achieved by approaching the climate change issues in a way similar to that of nuclear waste.

3.3.2 Approval context of waste disposal

Regulators all over the world formally base their decisions about the acceptability of a particular radioactive waste disposal system upon the related performance (safety) assessment. The key element of this assessment is dose evaluation. However, the requirements for the certainty/accuracy/validity of such evaluation are not clearly defined in advance and are a subject of development in the dose evaluation process itself. Therefore, dose evaluation, as well as the associated licensing procedure that builds on compliance assessment, seems to be a less appropriate approach due to the uncertainty involved. An alternative method for assessing human exposure in the framework of long-term safety assessment should be developed. Such a method, integrated with the concept of reasonable assurance (IAEA, 1997), should build on indicators of future exploitation of the environment - therefore a clear link to spatial planning in site selection process where human activities remain the basis for future exposure assessment (Kontic et al., 1999).

Since this approach is more fundamental, direct and transparent than dose or risk assessment, it is expected that it will be more powerful in confidence building among different social groups, i.e. scientists, regulators, the public and politicians. Eventually, it is also expected to be effectively applied in comparative evaluations of various energy options. In addition, certain ethical dilemmas in the licensing process connected to regulatory decision making in the presence of uncertainty and in the context of the disposal of long lived radioactive wastes, could also be reduced if dose or risk are avoided as individual numerical safety indicators.

3.3.3 Scientific treatment of specific uncertainty and predictions related to spent fuel

In this sub-section an analysis of the impact of uncertainty (associated with the quantity of radioactive waste produced by Krsko NPP in its anticipated operational time) on the waste-disposal strategy, particularly the selection of the disposal option, is presented. The dilemma is whether to build a shallow land repository for the LILW and to treat all high-level and long-lived waste separately; or to adopt deep geological disposal as the option for all waste types produced in the country. Tightly connected to these questions is the credibility of the evaluation of health consequences due to radioactive waste disposal. Indicators can, for example, be the dose and risk in the presence of uncertainty associated with the waste characteristics on the one hand, and societal characteristics and human habits in the distant future on the other. The approach and methods applied in the analyses were as follows:

- First, information about the present status of the waste was gathered. Attention was paid to the variability and accuracy of data on quantities, the radionuclide inventory and the activity of different types of waste.
- Then, based on this information, what may most likely be expected (with regard with these waste characteristics) by the end of the anticipated operational period of Krsko NPP, i.e. 2023, was estimated. The ORIGEN2 computer code was used for calculating isotope generation, activity build-up and depletion, and the decay heat of spent fuel (Croff, 1983), while a specific code was developed for calculations associated with LILW.
- The total activity, its time dependent change and the identification of radionuclides that mainly contribute to the activity in long timeframes, were applied as key information for discussing waste-disposal options for spent fuel (HLW). Changes (variations, uncertainty) in these characteristics were evaluated based on the technical specifications that are in place after the replacement of steam generators at the plant in the 17th fuel cycle in 2002. The variations considered were 3-5 % of U-235 in the fuel, and an operational period of the plant of five years more or five years less than that envisaged. The basic estimate was that Krsko NPP uses fuel with 4% U-235 in all future cycles and that it operates for 35 years.

The key input data for calculating burn-up and fuel characteristics in future cycles is not available at the moment. Consequently, certain assumptions had to be made. These were:

- 35 fuel cycles are assumed for the operational period of Krsko NPP.
- The average cycle burn-up is 12,000 MWd/tU. This value was adopted based on the following: The average number of effective days of full power operation per cycle is

324. Using 1,876 MW as the nominal power of the plant, and 48.7 t of uranium per cycle, one obtains 11,857 MWd/tU. When this is rounded off, 12,000 MWd/tU for burn-up and 320 effective days of operation at full power are obtained.
- A twelve-month cycle was assumed (i.e. the cycle lasts 365 days); the operational period is 320 days and the cooling (decay) period between cycles is 45 days (actually used for refuelling and maintenance).
 - One batch of fuel consists of 40 elements, containing 16.24 tonnes of uranium, and on average represents one-third of the total amount of fuel in the cycle (there are three different batches in the reactor during operation). Each batch remains in the reactor for the three following cycles – except the first, second, penultimate and last batches. The real situation is more complicated but corresponds roughly to these assumptions.
 - Being aware of the differences between these assumptions and the real operational data for Krsko NPP, a screening calculation of the activity of spent fuel for the first 13 cycles was made, for the purpose of further calibrating the model. The results for the model and those based on operational data differ very little – see Table 3 for details.
 - The content (mass) of uranium isotopes per fuel batch is given in Table 4.
 - The mass of zircaloy (Zr-40) per batch is 4012.5 kg; the mass of oxygen (O-16) is 2183.5 kg.
 - The average power per tonne of uranium is 37.5 MW; the average power of the batch is 609 MW.

	Activity after 7th cycle (Bq)	Cooling period (days)	Activity after 13thcycle (Bq)	Cooling period (days)
Source of operational data: NPP Krsko, and Ravnik and Železnik, 1990	7,5E+18	45	N.A.	N.A.
Source of operational data: NPP Krsko, and Božič (1998)	9,2E+18	45	2,5E+19	32
Model prediction	9,9E+18	45	1,2E+19	45
Difference (%), rounded	9-33		208	

Note: One should note that these differences are very low, taking into account that the order of magnitude of the values is E+19, and that the cooling periods differ, after the 13-th cycle, between the model and the real data. The latter is important if the activity of spent fuel decreases rapidly during the cooling period; this would mean that the activity drops by a factor of two over a two week period, i.e. in the period between 32 and 45 cooling days, which is the difference between the real data and the model.

Table 3. Comparison of the calculated (model) results and operational data

The calculated changes of activity of activation products (AP), actinides (ACT), fission products (FP) and total activity per fuel batch with time are presented in Figure 4. The

illustration is for model Batch 6; however, the figures are similar for other model batches. Batch 6 goes into the reactor in the fourth cycle (year). At the moment of irradiation, the total activity immediately increases by about eight orders of magnitude. Before that, the activity is constant at a level of 1.9×10^6 MBq (the activity of approximately 16 tonnes of non-irradiated fuel). During irradiation, this activity rises slightly from 1.23 to 1.28×10^{14} MBq, while during the cooling period of 45 days it drops by approximately two orders of magnitude. Each batch stays in the reactor for three successive cycles (except the first, the second, the penultimate and the last), whereupon the batch goes into the spent fuel pit for ultimate cooling and decay. It should be noted that the scale of both axes is logarithmic, so that the origins of axes are avoided in the illustrations.

Batch-enrichment (%)	Isotope (kg)			
	U-234	U-235	U-236	U-238
2.1	2.44	341.04	2.11	15894.25
2.6	3.25	422.24	2.59	15811.91
3.1	3.89	503.44	3.09	15729.58
3.4	4.22	551.67	0.81	15683.29
3.6	4.55	584.64	0.65	15650.49
3.9	5.36	633.36	1.30	15599.82
4.0	5.85	649.60	2.03	15581.96

Table 4. Mass of uranium isotopes in the fuel (per batch)

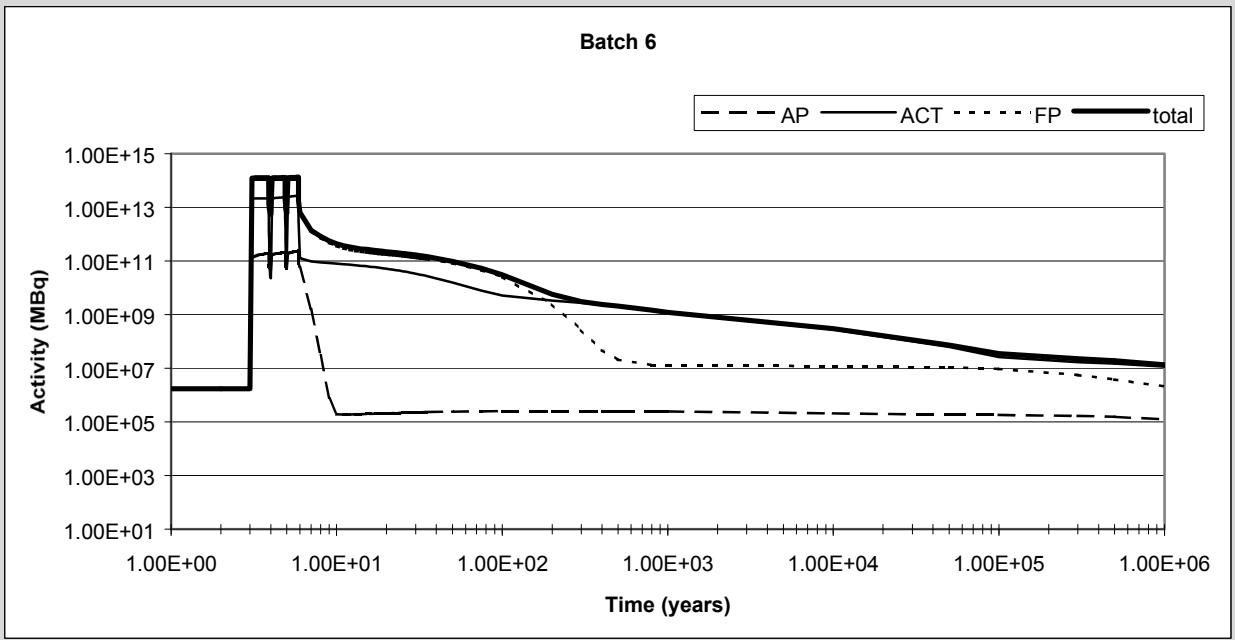


Fig. 4. Activity of model batch 6 over a million years

Model results for all the fuel are presented in Figure 5, which shows time changes in total activity. With regard to activity during the first 34 cycles, an almost linear increase can be identified due to the collection of spent fuel in the spent fuel pit - one batch per cycle/year. After the 35th cycle, i.e. at the end of the assumed operation of the plant, all three batches from the reactor will be placed in the spent fuel pit at the same time, which is seen as a noncontinuous increase in activity. Activity then decreases, depending on the radionuclides contained in the spent fuel. Note again that the scale of the axes is logarithmic. The values of total activity and decay heat for all spent fuel at selected time-points are summarised in Table 5.

The model adequately represents the overall operation of the plant. This was proved in the process of calibrating the model, where data for the past thirteen cycles were used for comparison. However, fuel enrichment, as well as other key operational elements in future cycles, may not remain constant, since an upgrade of the plant's power in parallel with the replacement of the steam generators has been achieved. Extension of the fuel cycles was also adopted/made. This was the reason for the analysis of the changes in the activity and radionuclide inventory of spent fuel, due to different fuel enrichment and the prolonged operation of the plant. The adopted variation in fuel enrichment was 1% above and below the value applied in previous calculations, i.e. 4% of U-235.

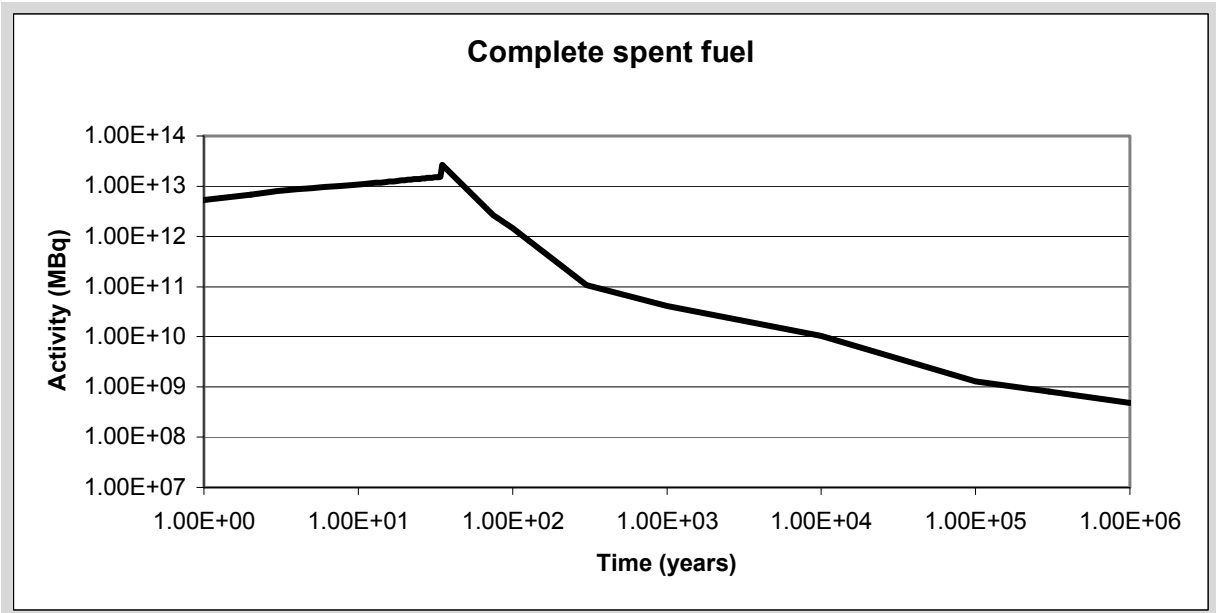


Fig. 5. Total activity of all the spent fuel as a function of time

With regard to the prolonged operation of the plant, a five-year variation was applied. All the variations were simulated for the period following the replacement of the steam generators, i.e. after the 17th cycle. The differences are presented in Figures 6 and 7, respectively. It is clear that the differences are so small that they can be neglected, since they are not relevant to the overall waste management strategy. Moreover, the conclusion which can be drawn from this result is that no benefit can be expected in terms of improved safety connected with radioactive waste disposal whether Krsko NPP were closed down immediately or operated for almost a further 12, or even 40 years as the new National Energy Programme suggests.

The results of the modelling show that the main contributors to fuel activity during the period approximately 200 years after irradiation are the fission products; after that, actinides will prevail. The total expected activity of the spent fuel after one million years is $4,8 \cdot 10^{14}$ Bq. The main contributors to this activity are the radionuclides of the U- and Np-chains. Residual thermal power is about $1.0 \cdot 10^5$ W approximately 200 years after irradiation, about $1.0 \cdot 10^4$ W after 10,000 years, and about 250 W after one million years.

The problem of uncertainty, which can be treated scientifically, is manageable. It was recognised that the basic characteristics of this waste can be accurately predicted, since all the sources of uncertainty are well defined, understandable and therefore controllable. Residual uncertainty does not change the overall picture of the waste, which would mean that the predictions could clearly be used as a basis for policy-making, i.e. creating a strategy for radioactive waste management, decision-making and also for communication with the public.

Time (years)	Total activity (MBq)	Decay heat (W)
1	$5.30 \cdot 10^{12}$	$5.55 \cdot 10^5$
2	$6.72 \cdot 10^{12}$	$7.19 \cdot 10^5$
3	$7.92 \cdot 10^{12}$	$8.71 \cdot 10^5$
4	$8.70 \cdot 10^{12}$	$9.54 \cdot 10^5$
5	$9.23 \cdot 10^{12}$	$1.01 \cdot 10^6$
10	$1.09 \cdot 10^{13}$	$1.13 \cdot 10^6$
15	$1.21 \cdot 10^{13}$	$1.22 \cdot 10^6$
20	$1.31 \cdot 10^{13}$	$1.31 \cdot 10^6$
25	$1.40 \cdot 10^{13}$	$1.38 \cdot 10^6$
30	$1.48 \cdot 10^{13}$	$1.45 \cdot 10^6$
35	$2.69 \cdot 10^{13}$	$2.72 \cdot 10^6$
75	$2.63 \cdot 10^{12}$	$3.08 \cdot 10^5$
100	$1.46 \cdot 10^{12}$	$2.23 \cdot 10^5$
300	$1.08 \cdot 10^{11}$	$8.44 \cdot 10^4$
1,000	$4.11 \cdot 10^{10}$	$3.52 \cdot 10^4$
10,000	$1.04 \cdot 10^{10}$	$8.23 \cdot 10^3$
100,000	$1.28 \cdot 10^9$	$6.82 \cdot 10^2$
300,000	$8.12 \cdot 10^8$	$3.80 \cdot 10^2$
1,000,000	$4.81 \cdot 10^8$	$2.53 \cdot 10^2$

Table 5. Total activity and decay heat of all the fuel from the Krsko NPP at selected time-points over a million years

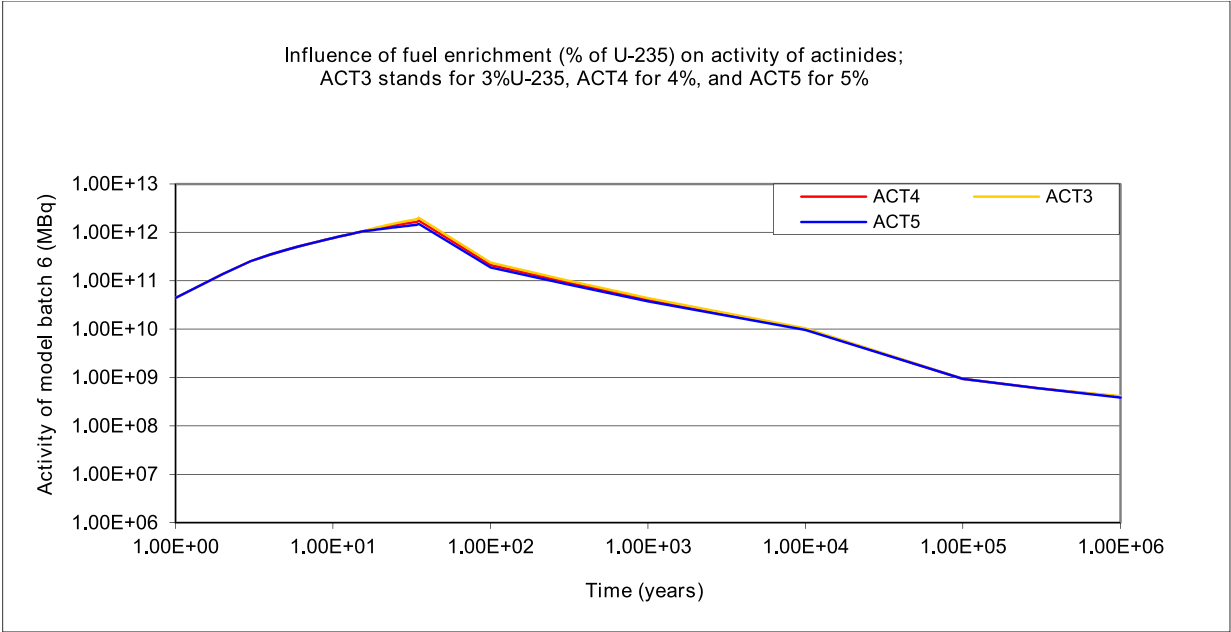


Fig. 6. Influence of fuel enrichment on activity of actinides (it is assumed that the change in fuel enrichment starts with the 17th cycle)

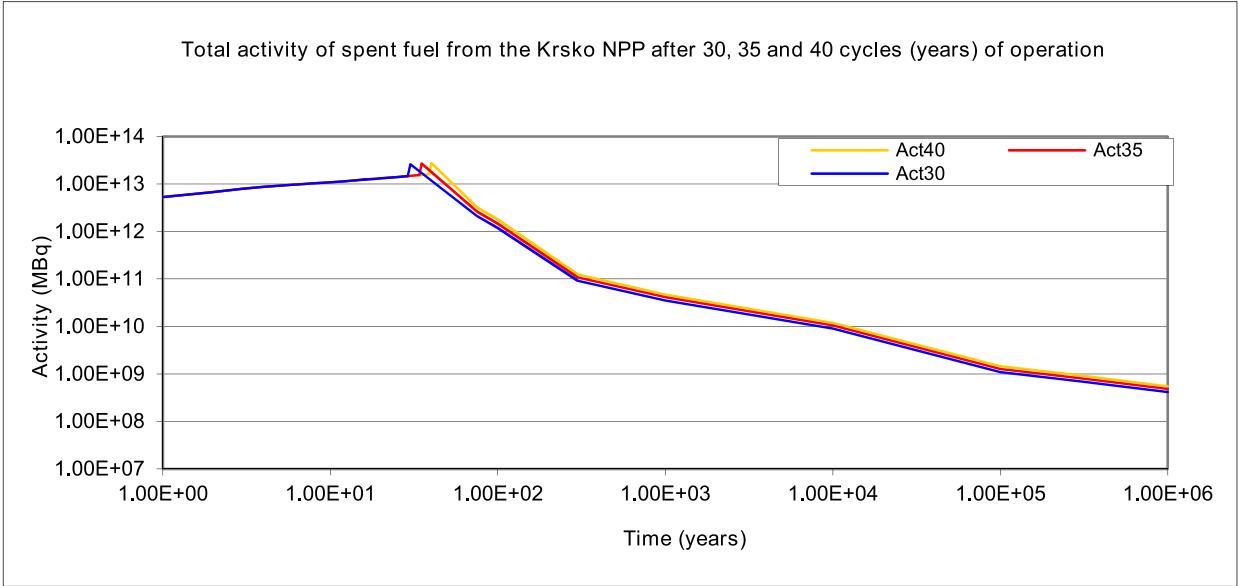


Fig. 7. Influence of extended or shortened operation of the Krsko plant on the activity of actinides in the complete spent fuel (the basic estimate is that the plant will operate 35 cycles)

With regard to confidence building connected to radioactive waste disposal, the recommendation is that prompt, clear and complete informing of all interested parties and the general public should take place. It should be clearly stated that the spent fuel from Krsko NPP, and a part of the decommissioned waste, will remain radioactive above today's prescribed levels for hundreds, thousands or even a million years from now. Consequently, a strategy built upon waiting for the activity to "disappear" cannot be effective. Doubts and uncertainties regarding safety assessments in a timeframe of a million years should also be revealed. At the same time, efforts should be made to present the concept of reasonable

assurance (IAEA, 1997) as the most reliable method, and as the basis upon which a waste management strategy can rely.

4. Concluding remarks

Strategic environmental considerations of nuclear power should inevitably cover the following (however, not restricted to):

- Comparative evaluation of electricity generation technologies; the evaluation should, in addition to topical consideration, thoroughly deal with the ways on how to overcome specifics and details of individual analysis of a certain technology which is usually influenced by the specific characteristics of the site compared to others in its category, the manufacturing and design characteristics, the power, lifetime and the operating conditions. Results are therefore difficult to transfer from a country to another or one generation unit to another, as most major environmental, economic and social impacts, with the exception of e.g., climate change, are heavily site-dependent. Application of proper indicators in such a comprehensive comparative evaluation may be of practical help and guidance;
- The energy system as a whole; the electricity grid and market issues are rarely taken into consideration when making comparative evaluation. Similarly, the issue of increased share of intermittent RES, its impact on the energy system, and consequent need for the adaptation of environmental impact approaches by taking into account actual share of each generation technology as provided in the energy system;
- Uncertainties; uncertainties and limitations of various methodologies may be acknowledged by the authors of the studies but those are rarely taken into account when results (or only some of them) are used by policymakers. Strategic considerations should provide guidance/recommendations on how to deal with the uncertainties in the decision-making process associated with comparative evaluation of different electricity generation technologies. This is especially relevant when deciding about long-term impacts, e.g. nuclear waste disposal or societal and spatial consequences of climate change.

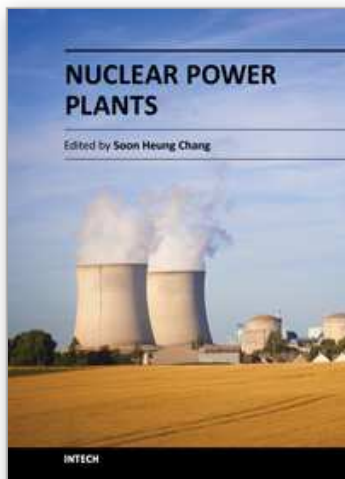
5. References

- Bohanec, M. & Rajkovič, V. (1999). Multi-Attribute Decision Modeling: Industrial Applications of DEX, *Informatica*, Vol. (23), 487–491.
- Bohanec, M. (2003). Decision Support in D. Mladenic, N. Lavrac, M. Bohanec, S. Moyle (eds.), *Data Mining and Decision Support: Integration and Collaboration*, Kluwer Academic Publishers, 23–35
- Božič, M. (1998). Izračun aktivnosti in zakasnele toplote goriva NE Krško, Seminar-podiplomski študij jedrske tehnike, Ljubljana (A Seminar: Activity and residual heat calculation at the NPP Krško; available in Slovene only)
- Canter, L. W. & Hill, L.G. (1979). *Handbook of Variables for Environmental Impact Assessment*, Ann Arbor Science Publishers Inc., Michigan
- Croff, A.C. (1983). Origen2: A versatile computer code for calculating the nuclide compositions and characteristics of nuclear materials, *Nuclear Technology*, No. 62, 335–352

- Dermol, U. & Kontić, B. (2011). Use of strategic environmental assessment in the site selection process for a radioactive waste disposal facility in Slovenia, *Journal of Environmental Management*, Vol. (92), 43-52
- EC - European Commission (1998). Handbook on Environmental Assessment of Regional Development Plans and EU Structural Fund Programmes, EC-DGXI: Environment, Nuclear Safety and Civil Protection, Bruxelles
- EC - European Commission (1999). Environment and Sustainable Development. A Guide for the ex-ante evaluation of the environmental impact of regional development programmes, *Series: Evaluation and Documents* No. 6, Bruxelles
- EC - European Commission (2009). Study concerning the report on the application and effectiveness of the SEA Directive (2001/42/EC): Final report, European Commission, DG ENV, COWI, 12.07.2011, Available from <http://ec.europa.eu/environment/eia/pdf/study0309.pdf>
- Eurelectric (2011). 20% Renewables by 2020: a eurelectric action plan. Summary Report, Available at <http://www.eurelectric.org/RESAP/About.asp> (9 January 2012)
- Hansson, S.O. (2011). Ethical and philosophical perspectives on nuclear waste, in B. Berner, B.-M. Drottz Sjöberg, E. Holm (eds.), *Social Science Research 2004-2010, Themes, results and reflections*, ISBN 978-91-978702-2-1, CM Gruppen AB, SKB, Stockholm, 137-149
- IAEA (1994). Siting of geological disposal facilities, *Safety Guide*, Safety Series, Vienna, 4-19
- IAEA (1997). Regulatory decision making in the presence of uncertainty in the context of the disposal of long lived radioactive wastes, IAEA-TECDOC-975, 22-23
- IAEA (1999). Health and environmental impacts of electricity generation systems: Procedures for comparative assessment, TRS No. 394, IAEA, Vienna
- IAEA (2000). Enhanced electricity system analysis for decision making - A Reference Book, DECADES Document No. 4, IAEA, Vienna
- IPCC (2011). Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN), Available at <http://srren.ipcc-wg3.de/> (9 January 2012)
- Kontić, B., Kross, B. C. & Stegnar, P. (1999). EIA and long-term evaluation in the licensing process for radioactive waste disposal in Slovenia, *Journal of Environmental Assessment Policy and Management*, Vol. (1), No. 3, 349-367
- Kontić, B., Bohanec, M. & Urbančič, T. (2006). An experiment in participative environmental decision making, *The Environmentalist*, Vol. (26), 5-15
- Kontić, B. & Kontić, D. (2011). A viewpoint on the approval context of strategic environmental assessments, *Environmental Impact Assessment Review*, doi: 10.1016/j.eiar.2011.07.003
- Laukkanen, S., Kangas A. & Kangas J. (2002). Applying voting theory in natural resource management: A case of multi-criteria group decision support, *Journal of Environmental Management*, Vol. (64), 127-137
- Munda, G., Nijkamp, P. & Rietveld, P. (1995). Monetary and non-monetary evaluation methods in sustainable development planning, in K. G. Willis, K. Button, P. Nijkamp (eds.), *Environmental Valuation Volume II: Multi-Attribute Programmes, Validity, Allocation Issues in Case Studies*, Series Environmental Analysis and Economic Policy, Edward Edgar Publishing, Inc., Northampton

- Ravnik, M., Železnik N. (1990). Izračun izotopske sestave in aktivnosti goriva JE Krško, IJS-DP-5851, Ljubljana (Technical Report on isotopic content and activity of spent fuel at Krško NPP; available in Slovene only)
- SKB - Swedish Nuclear Fuel Management Company (2011). Distinctive international strategies, in B. Berner, B.-M. Drottz Sjöberg, E. Holm (eds.), *Social Science Research 2004-2010, Themes, results and reflections*, ISBN 978-91-978702-2-1, CM Gruppen AB, SKB, Stockholm, 42-44
- Taylor, N. (1980). Planning theory and the philosophy of planning, *Urban Studies*, Vol. (17), 159-172
- Therivel, R. (2005). *Strategic Environmental Assessment In Action*, Earthscan, London, pp. 7-19.
- URS (2010). Preliminary report on environmental impacts of different energy technology options for Slovenia, WSMS-OPS-09-0001, Washington

IntechOpen



Nuclear Power Plants

Edited by Dr. Soon Heung Chang

ISBN 978-953-51-0408-7

Hard cover, 340 pages

Publisher InTech

Published online 21, March, 2012

Published in print edition March, 2012

This book covers various topics, from thermal-hydraulic analysis to the safety analysis of nuclear power plant. It does not focus only on current power plant issues. Instead, it aims to address the challenging ideas that can be implemented in and used for the development of future nuclear power plants. This book will take the readers into the world of innovative research and development of future plants. Find your interests inside this book!

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Branko Kontić (2012). Strategic Environmental Considerations of Nuclear Power, Nuclear Power Plants, Dr. Soon Heung Chang (Ed.), ISBN: 978-953-51-0408-7, InTech, Available from:
<http://www.intechopen.com/books/nuclear-power-plants/strategic-environmental-considerations-of-nuclear-power>

INTECH
open science | open minds

InTech Europe

University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

© 2012 The Author(s). Licensee IntechOpen. This is an open access article distributed under the terms of the [Creative Commons Attribution 3.0 License](https://creativecommons.org/licenses/by/3.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

IntechOpen

IntechOpen