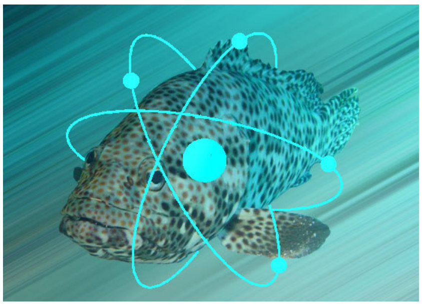

CHERNE

Cooperation for Higher Education on Radiological and Nuclear Engineering

Erasmus Intensive Programme Project (IP)

ICARO

Intensive Course on Accelerator and Reactor Operation

01/03/09 – 14/03/09

– Lisboa, Portugal –

Alma Mater Studiorum Universita' di Bologna, Italy
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Final report on the Round tables:

1. Nuclear and Sustainable Development

2. Ethics and the Principle of Justification – the case of Nuclear Technology Assessment –

Herwig Janssens - editor
XIOS Hogeschool Limburg, dptm. Nuclear Technology, Diepenbeek, Belgium

– 2009 –

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Annexes

Nuclear and Sustainable Development: an Introduction

Herwig Janssens
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Abstract
With this paper we would like to give an introduction to and present a reference framework for the discussion on the challenge of nuclear and sustainable development.

One of the main objectives of the Erasmus Intensive Programme '*Intensive Course on Accelerator and Reactor Operation, ICARO*' [[1]], organised by the Cherne network [[2]], is to contribute to the discussion on the main challenge of the nuclear industry:

- to maintain, develop and disseminate the knowledge in nuclear engineering
- to enhance the level of expertise needed for the safety of existing facilities as well as for the expected new developments.

This is in agreement with the needs and challenges of the European Union, as stated by the Lisbon Strategy in March 2000, i.e. the preservation of the energy supply:

- by keeping all the energy options open
- by the retention and enhancement of the technological and scientific skills, e.g. in the nuclear field

The concept of sustainable development is defined in the so-called Brundtland Report [[3]] as:

- a development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

To introduce the concept of sustainable development in the nuclear field, we use the reports prepared by the Nuclear Energy Agency NEA of the Organisation for Economic Cooperation and Development OECD [[4]] and by the European Sustainable Nuclear Energy Technology Platform SNE-TP [[5,6]]. These reports consider the concept of sustainable development not only, but mainly from the nuclear and technological point of view. Of course there are other – non nuclear – points of view, which also can be worthwhile and valuable.

Sustainable development incorporates:

- equity within and across countries as well as across generations
- integration of economic growth, environmental protection and social welfare
- implication of long term responsibility.

Energy has links with the three dimensions of sustainable development:

- economy
- environment
- society.

Sufficient energy supply is essential for economic and social development. As energy use will continue to grow, its health and environmental impacts will have to be controlled, tempered or mitigated in order to achieve sustainable development goals. The main challenge of sustainable development in the energy sector is to extend the benefits of energy supply to the whole world, and to future generations, without undermining the carrying capacity of the environment. Especially in developing countries large amounts of energy will be needed to improve standards of living.

Technology is necessary to support economic development but needs careful control and monitoring to be consistent with the social and environmental goals of sustainable development. Economic competitiveness is a prerequisite for a viable technology. Assessments of competitiveness should be based upon comparisons of full costs to society including social and environmental costs.

Nuclear energy has to compete with a broad range of alternatives, including fossil fuels and renewable energy resources, on the basis of full generation costs – i.e. capital, operation, maintenance, fuel costs and decommissioning. The huge capital costs of nuclear power create financial risks, especially in deregulated markets (private investment and/or taxpayer involvement).

As many other energy resources nuclear energy is not inexhaustible, even if the resource base is extended through recycling of fissile materials and/or implementation of advanced fuel cycles (see generation IV and fusion reactors as a real and reliable solution for the future or as perceived by some critics mainly as wishful thinking).

Climate change and global warming is one of the challenges to sustainable development. Nuclear energy is essentially carbon-free and can eventually contribute to reducing the emissions of greenhouse gases, if society accepts nuclear energy as a reliable option.

Independent and effective regulation and control of nuclear technology is a primary condition for the safe operation of nuclear power plants. Radioactive releases, sometimes small and sometimes considered by technologists as irrelevant, up to historically well-known severe accidents, are of public concern, and have to be kept under control by technology development and expertise. This has to be supplemented by nuclear safety regulations, measures and legislation, and by a large (national and international) institutional framework.

Although the risks associated with radiation are among the most extensively studied hazards known, several factors increase the public anxiety about radiation (invisible, unfamiliar, probabilistic, perception of uncontrollability, …). The basic radiation protection principles of justification, optimisation and dose limitation, all of them based on the precautionary principle, are not generally understood by the public at large.

The problem of radioactive waste and decommissioning of existing and future nuclear facilities is a major public concern. Although geological repositories are considered by specialists as a safe and reliable solution, this is not always perceived like that by the public at large, and as a consequence by decision makers (political and others).

The risk of nuclear weapon proliferation is a public concern in connection with peaceful applications of nuclear energy. In view of sustainable development nuclear energy should not contribute to the proliferation of nuclear weapons.

Some countries (and governments) have come to the conclusion that nuclear energy can be considered as a sustainable technology, while other have decided the opposite, depending on a wide range of factors, many of them specific to local situations (availability of other resources, financial investment and risk, public acceptance, …).

Some technologically highly developed countries with an established safety culture and quality consciousness will be investing in new nuclear programmes based on evolutionary or revolutionary technology. At the same time other countries, probably less technologically developed or with less established safety culture or quality consciousness, cannot be denied the same technology, even if there are lower safety standards, eventually with a higher risk of accidents, radiation exposure, proliferation or terrorist attacks. Technology transfer, technical assistance and cooperation will be especially important in the light of the growing demand for energy in these countries.

Some of the factors determining the discussion are:

- risk and uncertainty (including the precautionary principle)
- perception of risk an uncertainty
- the social dimension (equity and participation)
- natural, non-renewable and/or renewable resources
- technological development (education, research, innovation, economical competitiveness)
- governmental policy in view of scientific and technological discourse versus general public debate
- the impact of decision influencing bodies (scientific community, labour and political organisations, industrial lobbies, …) and of so-called 'counter-experts' (many times highly respectable in knowledge and ethical point of view).

Public participation in policy making and public acceptance of processes and decisions are central to meeting the social goals of sustainable development in terms of equity and transparency. In democracies, public concerns and political aspects of projects and policy measures have to be addressed by decision makers. For nuclear energy, as for a number of other technologies, most concerns arise from the public perceptions of the risks involved. Achieving acceptability will require an understanding of risk perception and communication, and the development of processes and institutions that involve greater participation by the public.

The OECD report marks that:

> 'addressing the public concern is essential to meet the social objectives of sustainable development. For this purpose and in the light of the widespread public concern about nuclear risks, it is necessary to include the public in a democratic decision-making processes through which it gains confidence that its concerns are being heard and addressed. The implementation of nuclear energy projects requires a participation of the public at the national and local level, and the exchange of a broad range of information and perceptions covering scientific, technical, economic and social aspects. It is important to allow the public to put social, ethical and political issues related to nuclear energy into perspective with the issues raised by alternatives, including the different liabilities passed to future generations such as long-lived radioactive waste, climate change or resource exhaustion. It is the responsibility of governments to create the conditions for decision-making processes to be consistent with intergeneration equity and the social objectives and environmental protection goals of sustainable development.'

As sustainable development is not only nuclear development, any of the statements in this paper has to be analysed critically and other points of views should be taken into account.

In the interest of the whole world – society, economy and environment – development has to be sustainable development.

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Ethics and the Principle of Justification
- the case of Nuclear Technology Assessment -

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Abstract
The use of nuclear technology brings along a variety of societal implications that complicate its 'societal justification', especially in the frame of designing an energy policy that meets the criteria of 'sustainable development'. The roundtable will analyse aspects of nuclear technology assessment, starting from the complexity of nuclear risk governance and linking these insights to questions on knowledge use and deliberation formats that characterise the 'political act of justification'.

Public acceptance of nuclear energy technology is nowadays regarded as an essential element for any energy policy that envisages the future use of nuclear energy as a part of the production mix. Nevertheless, there doesn't seem to be a clear idea of how this acceptance should be acquired, not within the nuclear community and not with national governments of countries with nuclear. Added to the technological challenges, it appears that the use of nuclear technology brings along a variety of societal implications that complicate its 'justification', especially when it comes to assess it in the frame of designing an energy policy that meets the criteria of 'sustainable development'.

Today, the nuclear topic is hotter than ever in national and global politics, and this mainly in three different contexts: 1) radioactive waste disposal in relation to issues of long term safety and social justice, 2) nuclear as a (no-)solution to climate change, the latter said to be the 'biggest challenge to humankind' today and 3) the threat of proliferation of nuclear weapons in a new global 'politics of power' between nation states.
In all discussions within those three contexts, nuclear advocates make reference to supportive arguments such as the stability and reliability of the fuel market, the low carbon dioxide burden of the nuclear fuel cycle and the competitive price of nuclear electricity in base load production. In addition, they refer to the good safety records of modern NPP's and 'even safer' designs for future plants, claim to have solutions for radioactive waste disposal available and state that fuel cycles can be made proliferation-safe by a combination of technical measures and security controls. Opponents, from their side, question reactor safety by making reference to past incidents and accidents and question security by pointing at the risk of proliferation and terrorism caused by 'irresponsible regimes'. They claim that there is no solution for waste and that the CO_2 emissions of the nuclear fuel cycle are underestimated.
In short, one side states that 'nuclear is sustainable' while the other side says it is not. In addition, in one country at one point in time, EU barometers and other questionnaires reveal a majority of the public to be in favour of nuclear, while in another country, the public is against. Who is right and who is wrong? Is it a matter of keeping emotions out of rational decision making? Does the challenge come down to 'explaining' the public that nuclear is (not) acceptable (safe, competitive) and (not) 'sustainable' by providing them with 'objective facts', or is the situation more complex than that?

Instead of trying to formulate an answer to this 'who is right and who is wrong?' - question, this roundtable aims to tackle the complexity of the problem in a more fundamental way. We will look at what essentially complicates the question of justification of nuclear technology and do this in three steps:

1 - Firstly we will analyse the complex character of risk assessment in the case of societal justification of nuclear technology;
2 - Secondly, we will take a critical look at how decisions on nuclear are taken today;
3 - Thirdly, based on the insights from the previous steps, we try to answer three essential questions with regard to the 'political act of justification':

(1) what should and can we know in order to make 'rational' and fair decisions on nuclear, and how should and can this knowledge be used in the decision making?
(2) how should and can this process of decision making be organised?
(3) how should and can we assure that this process of decision making meets the criteria of sustainable development?

The roundtable will be organised in two parts. The first part is an interactive lecture that introduces the three steps and questions as described above. We will touch upon ideas of philosophy of ethics and science and political philosophy and make connections to what these would mean in the case of nuclear technology assessment. In a second part, working groups first discuss the three questions in relation to one context chosen out of the three mentioned above (radioactive waste, climate change, proliferation) and then express their thoughts in a closing general discussion.

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Bio
Gaston Meskens has master degrees in theoretical physics and nuclear physics from the University of Ghent and starts a PhD in philosophy at the University of Brussels in 2009. He is also a lecturer on 'Physics of Radioactivity', 'Ethical Aspects of Radiological Protection' and 'The Philosophy of Justification – the Case of Nuclear Technology Assessment' in various national and international course programmes.
His actual research focuses on political philosophy of global decision making in the frame of sustainable development and on philosophy of science in the interest of policy supportive research. In this, his research develops on two tracks:
1) As a researcher in the Programme of Integration of Social Aspects into Nuclear Research (PISA) of the SCK•CEN, he takes nuclear technology as a case in order to study the complexity of societal justification in technology assessment (TA). His research interests are TA and policy principles (sustainable development, precautionary principle, risk governance), TA and policy methodologies (deliberative democracy, expert culture) and TA and ethics (justification, misuse, involvement, accountability).
2) His current philosophical research inquires the performative and communicative character of the science-society-policy interface in terms of both its effectiveness and normative grounds, and this based on the premise that any inquiry on criteria for 'good' governance will come down to an analysis of attitudes in and methods of political interaction, both in terms of using knowledge and mandates. In this research track, the policy processes devoted to global (supranational) governance of energy and climate change are used as a case.

In these contexts, he has build up more than ten years of experience in participative and interactive research in the policy processes of the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Commission on Sustainable Development. He is also an active member of the core group of the Constituency of Research-oriented Independent Non-Governmental Organisations towards the UNFCCC. In the European research field, he participated in several EC Framework Programme projects on governance of radioactive waste and is involved in designing future related projects under FP7. He has participated as invited expert in Belgian parliamentary hearings on the ethics of nuclear technology, in several Technical Committees of the International Atomic Energy Agency and of the OECD and in UN missions in the frame of sustainable development.

The Concept of Sustainable Development in General and the Implication for the Energy Sector in Particular

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Abstract
This paper discusses the basic concept of sustainable development. Its environmental, social and economic dimensions and indicators are described with respect to Energy.

The Brundtland Commission, formally the World Commission on Environment and Development, first coined the term Sustainable Development in 1987. It is defined as "The development, which meets the needs of the present without compromising the ability of future generations to meet their own needs" [1]. Sustainable development is more like a direction for a journey than a destination. The immediate objective is to take steps in the direction that increases the range of available options rather than exclude any of them. The concept of sustainable development can be divided into three key elements environmental sustainability, economic sustainability and social sustainability.

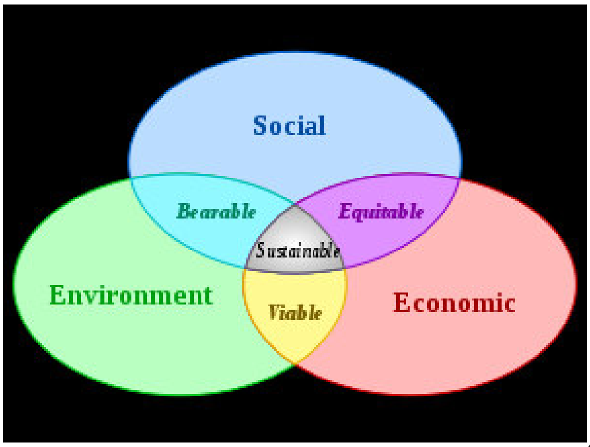

Fig 1. The three pillars of sustainable development [4]

In theory equilibrium between the three is required to fulfil all the criteria for sustainable development. However, in practice trade-offs are made between environmental, social and economic dimensions of sustainability. Thus we can differentiate the concept into strong sustainability where trade-offs are restricted and weak sustainability where trade-offs are acceptable. Some elements of the biosphere cannot be traded off and are called critical natural capital.

Energy is like blood for our modern civilization. It is essential for procuring our basic requirements of food, water, clothing and shelter. It has a direct impact on poverty and the standard of living. Energy is a vital requirement for economic development and prosperity. Reliable and adequate energy supply is a prerequisite for all developing countries to evolve from subsistence agricultural economies to modern industrial and service-oriented societies. Energy supply affects jobs, productivity and development. The production, distribution and use of energy create pressures on the environment. Fossil fuels generate atmospheric emissions and particulate matter. Nuclear energy produces harmful radiation and radioactive waste. For the generation of Hydropower, rivers are dedicated to dams and power production causing changes in stream flow and in many cases the flooding of the vicinity. There is no energy production or conversion technology without risk or waste production. The environmental impacts can depend greatly on how energy is produced and used, the fuel mix, the structure of the energy systems and related energy regulatory actions and pricing structures.

The various impacts of human activities affecting our advancement towards sustainability need to be assigned a value like giving a monetary value to any product or service. These values are called measures or indicators, which are used to strive towards sustainable development. To identify the indicators we first need to know the current status concerning energy and economic sustainability, what needs to be improved and how these improvements can be achieved. Second, it is important to understand the implications of the chosen energy, environmental and economic plan, and their impacts on the shaping of development and on the feasibility of making this development sustainable. Lastly trade-offs will be unavoidable. Thus informed and fair choices need to be made on policy, investment and corrective action.

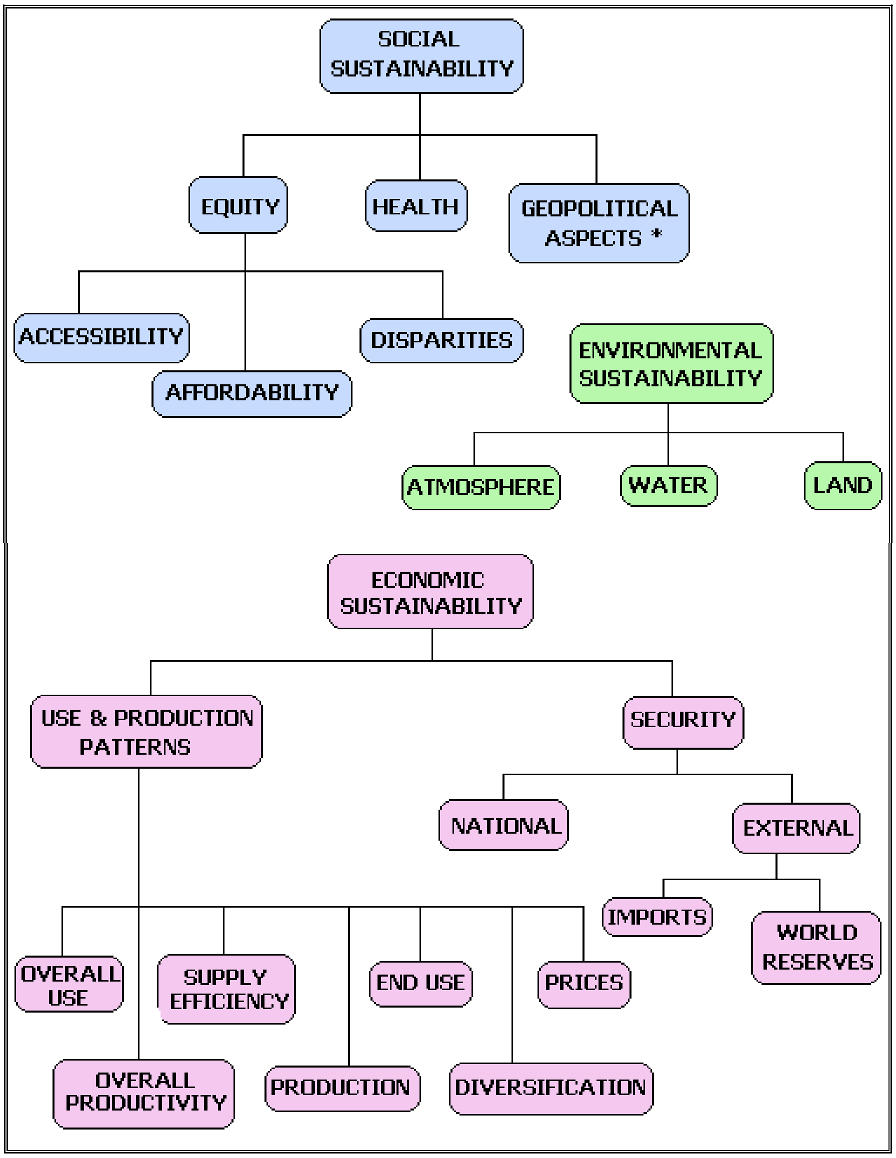

Fig 2. Indicators for each of the dimensions of sustainable development

Each set of indicators expresses consequences of the production and use of energy. Fig. 2 gives the different themes and sub-themes for Energy in each dimension. Taken together, the indicators give a clear picture of the whole system, including inter-linkages and trade-offs among various dimensions of sustainable development, as well as the longer-term implications of current decisions and behavior.

Changes in the indicator values over time mark the progress or lack of progress towards sustainable development.

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Comparison of nuclear energy and alternatives in view of sustainable development (excluding competitiveness)

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Abstract
Sustainable development is an important topic in view of the common welfare of our planet. We have to realize this as soon as possible if we want to decrease our ecological footprint. Sustainable development is valuable in all aspects of our society, one of these aspects is energy production.
Currently none of the known energy resources meets the requirements of sustainable development. In the text below we will discuss nuclear energy and alternative forms of energy on account of sustainable development.

Sustainable development

There are several interpretations of sustainable development. One can define this as a development that meets the present need without compromising the ability of future generations to meet their own needs [1].
The definition as given above seems a very simple statement and should always be applied in every human activity. The conditions of this definition are definitely not met, the reason is mostly historical and due to the fact that the definition can be interpreted in several ways.
If the definition is taken very strictly, we believe nobody should use fossil fuels, produce any waste or use any commodities which are not fully recyclable. These restrictions demand a total change in human lifestyle and are almost impossible to apply.
If the definition is applied in a short term view only the most urgent problems, like global warming, can be considered. The solution for this problem is a drastical reduction in the emission of greenhouse gasses.
The long term view will be to strictly apply all conditions of the definition. This cannot be done instantly and therefore we need a transition period in which the solutions for the future are developed and applied when possible. The energy consumption should also be reduced in this period but the demand for electricity will probably still increase [2].

In the text below the principles of sustainable development will be compared to different energy resources.

Energy resources

There are three main groups of energy resources i.e. fossil fuels, renewable energy and nuclear energy.

Fossil fuels are a high quality form of stored solar energy – the result of millions of years of photosynthesis that grew plants and the animals that fed upon them, both of whose decomposing remains were trapped in sediments and eventually transformed through subterranean pressures into natural gas, oil and coal [3].

The term renewable and green energy is referred to as energy which is environmentally friendly and non-polluting. They include solar power, wind power, hydro power and bio-fuels. These energy resources are promoted as the solution for global warming and pollution.

Nuclear energy comprehends nuclear fission and nuclear fusion. In both processes the energy is produced by conversion of binding energy into heat, which is used to generate electricity.

Comparison of the different types of energy resources in view of sustainable development

The different types of energy resource can be compared on the level of their ecological soundness, waste, depletion of primary fuels and applicability.

Ecological soundness
One of the main aspects of global warming are the greenhouse gasses. The energy sector is responsible for about 21% of the greenhouse gas emission. As one can see in Figure 1 the fossil fuel power plants have the largest share in greenhouse gas emissions. Not only the direct emission through burning of these fuels but also the mining, construction, transport and processing have a large share in the greenhouse gas emissions [4].
Notice that this last remark is also valid for the nuclear sector, but the process for the generation of electricity is greenhouse gas emission free (see Figure 2) [5].

Waste
Nuclear waste is the most criticized form of waste and it is a big problem nevertheless solutions are available. One can think of nuclear waste repository in clay layers today and maybe closed fuel cycle and partitioning & transmutation in the future. These solutions are definitely not accepted by many people and have to prove themselves to get more accepted [6].
Renewable and green energy seems ecologically sound, but the construction of some types of electricity producers (e.g. photovoltaic solar panels, wind turbines, etc.) contributes to the waste problem [7]. This is also valid for the construction of nuclear power plants.

Depletion of primary fuels
Energy resources which use commodities[1] should be avoided in the view of sustainable development. They all deplete the earth's resources and finally will not be economically viable due to rising fuel prices.
The goal to only use renewable energy is hard or even impossible to reach.

Applicability
Fuel consuming energy supply, without any dependencies, is the only form of energy which can be applied everywhere, because they do not rely on conditions like wind, water and sun availability. Major disadvantages of fuel consuming energy forms are mining and transportation difficulties. This is especially the case for nuclear energy. Remark that solar and wind energy are quite geologically bound. Some countries have the advantage of using the natural resources fully.

Conclusion and expectations

It is impossible to give a straight answer concerning issues like sustainable development and energy. Trade-offs[2] will always be necessary. Scientific research regarding renewable and nuclear energy (generation IV and fusion) is still in initial phase. Keep in mind that the construction of such energy producers will undo the advantages of sustainable development. Also the nuclear sector has problems regarding this topic. Research on both terrains has to be stimulated and should be equally subsidized. At the moment one should manage the golden mean. In the future we hope that technology is capable to find a covering solution.

[1] **Commodity:** an article of trade or commerce, especially an agricultural or mining product (e.g. uranium, petroleum, coal) that can be processed and resold.
[2] **Trade-off:** a situation that involves losing one quality or aspect of something in return for gaining another quality or aspect. It implies a decision to be made with full comprehension of both the upside and downside of a particular choice.

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Annex

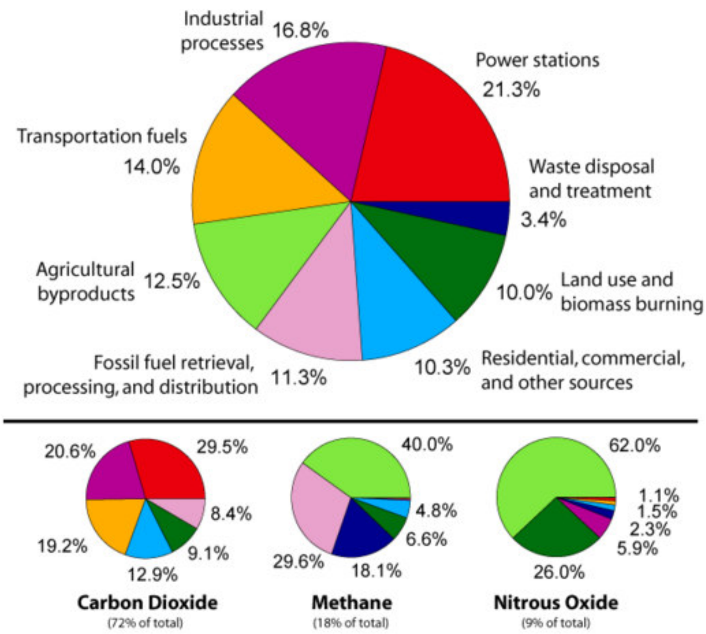

Figure 1 Annual greenhouse gas emissions by sector [4]

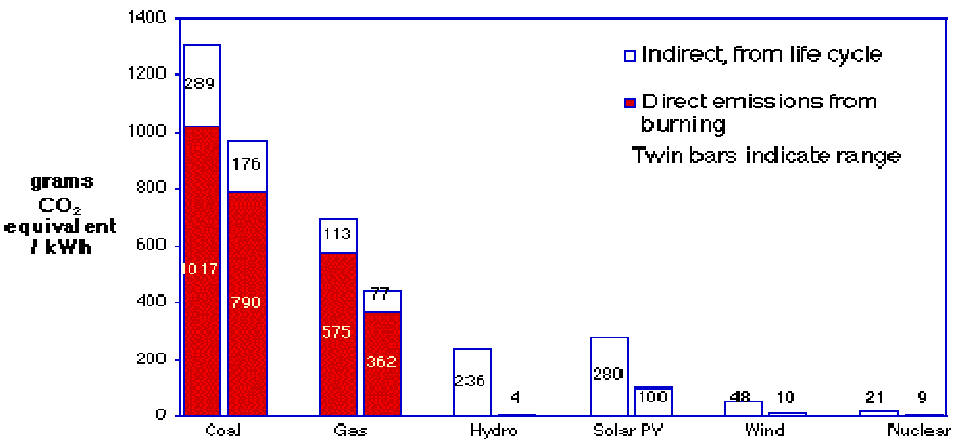

Figure 2 Greenhouse gas emissions from electricity production [5]

Assessment of competitiveness based on comparison of full costs to society including social and environmental costs

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Abstract

Nuclear power is on the verge of a remarkable comeback. The Kyoto Protocol requires industrialized countries to limit Greenhouse Gas emissions in 2008-2012. Nuclear Energy becomes an alternative to fossil fuels that can generate electricity producing no carbon emissions, i.e., a clean energy source. It requires an accurate analysis of the costs to evaluate its competitiveness with other energy forms.

Existing well operated nuclear power plants have proven to be a competitive and profitable source of electricity, largely due to significant improvements in nuclear plant reliability and improved safety records. Nuclear can provide the reliable, large-scale electricity necessary for industry and large urban areas. Evidence of this can be found in the usual practice of extending a nuclear plant's life.
Future competitiveness of nuclear power will depend substantially on the additional costs which may befall to coal-fired power generation, and on the cost of gas for gas-fired plants. It is uncertain how the real costs of meeting targets for reducing sulphur dioxide and greenhouse gas emissions will be attributed to fossil fuel plants.
There are three broad components: capital, finance and operating costs. Capital and financing costs compose the project cost [1].

- **Capital cost** may comprise several items: the bare plant cost, the owner's costs (land, cooling infrastructure, administration and associated buildings, site works, switchyards, project management, licences, etc), cost escalation and inflation.

- **Financing costs** will depend on the rate of interest on debt and the debt-equity ratio.

- **Operating costs** include operating and maintenance (O&M) plus fuel, and need to allow for a return on equity.

External costs are the impacts or damages caused by the energy producing activities on the health and environment and which are not included in the market price of electricity. Matters are complicated because the use of electricity provides also benefits to society that must be balanced against the losses incurred in its production and use [2]. Nuclear power in general generates low external costs, even after the very low probability of accidents with very high consequences and the fuel cycle impact are included. Several studies have attempted to quantify the external costs associated with electricity generation, an example is the European method ExternE, released in mid 2001 [3]. ExternE methodology has been applied to a wide range of fuels, different technologies and locations. For example, in Germany it has been used to estimate the damage costs due to global warming (Table 1).

	Coal	Lignite	Gas	Nuclear	PV	Wind	Hydro
Global warming	1.60	2.00	0.72	0.03	0.33	0.04	0.03

Tab 1. Quantified marginal global warming costs of electricity production in Germany (€cent/kWh).

The following figure (Fig.1) shows the relative effects of capital and fuel costs [4].

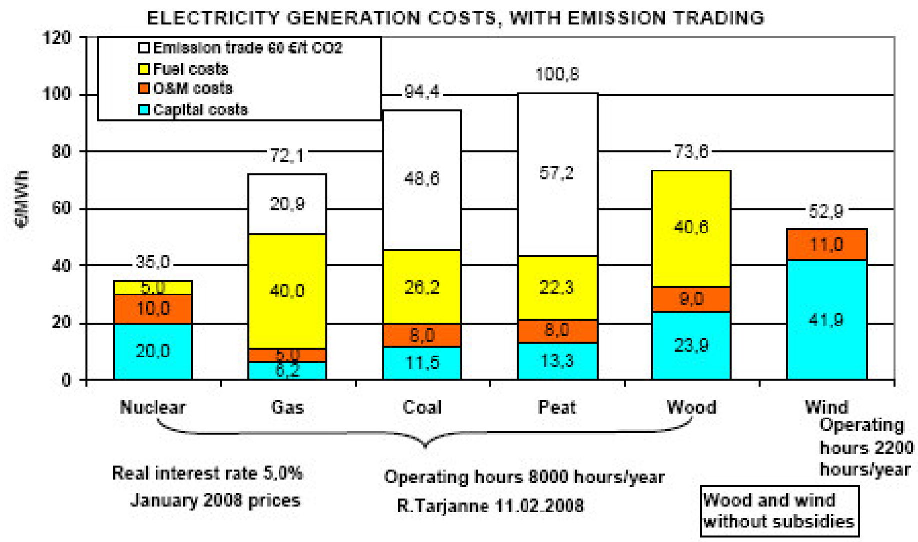

Fig.1 The electricity generation costs of the power plants with the emission price of 60 €/tCO_2

The relatively high capital cost of nuclear power means that financing cost and time taken in construction are critical, relative to gas and even coal. But the fuel cost is very much lower, and so once a plant is built its cost of production is very much more predictable than for gas or even coal.
For nuclear power plant decommissioning and final waste disposal are considered internal costs, compared to other technologies.

Generally, plant choice is likely to depend on a country's international economic situation. Nuclear power is very capital-intensive, while fuel costs are much more significant for systems based on fossil fuels. Therefore if a country has to choose between importing large quantities of fuel or spending a significant capital at home, simple costs may be less important than wider economic considerations.

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Radioactive Waste Management in view of Sustainable Development

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In the OECD approximately 300 millions tons of toxic wastes are produced each year, but conditioned radioactive wastes amount to only 81.000 cubic meters per year. In countries with nuclear power, radioactive wastes comprise less than 1% of total industrial toxic wastes. All toxic wastes need to be dealt with safety, not just radioactive wastes. All parts of nuclear fuel cycle produce some radioactive waste and the cost of managing and disposing of this is part of the electricity cost.

The sustainable development and his implication

The concept of sustainable development was elaborated in the late 1980's and defined as a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The main objective in managing and disposing of radioactive (or other) waste, in view of this definition of sustainable development, is to provide an acceptable level of protection for human health and simultaneously a good level of protection for environment too [1].

The origin of radioactive wastes and their classification

Radioactive wastes originate not only from nuclear plants but also from application in medicine and industries and decommissioning of nuclear facilities. For the classification of radioactive wastes there are several approaches, but the following is generally accepted:

Very Low Level Waste & exempt waste: excluded from regulatory control because radiological hazards are negligible. This kind of waste consists mainly of demolished material produced during rehabilitation or dismantling operations on nuclear industrial sites. Other industries, such as food processing, chemical, steel etc also produce VLLW as a result of the concentration of natural radioactivity present in certain minerals used in their manufacturing processes.

Low Level Waste (LLW): contains enough radioactive material to require action for the protection of people, but not so much that it requires shielding in handling or storage. This kind of waste are generated from hospitals and industry, as well as in the nuclear fuel cycle. It comprises paper, rags, tools, clothing, filters etc which contain small amounts of mostly short-lived radioactivity. To reduce its volume, it is often compacted or incinerated before disposal. It comprises some 90% of the volume but only 1% of the radioactivity of all radwastes.

Intermediate Level Waste (ILW): requires shielding. If it has more than 4000 Bq/g of long-lived (over 30 year half-life) alpha emitters it is categorised as "long-lived" and requires more sophisticated handling and disposal. ILW contains higher amounts of radioactivity and normally requires shielding. Shielding can be barriers of lead, concrete or water to give protection from penetrating radiation such as gamma rays. ILW typically comprises resins, chemical sludges and metal fuel cladding, as well as contaminated materials from reactor decommissioning. It may be solidified in concrete or bitumen for disposal. Generally short-lived waste (mainly from reactors) is buried, but long-lived waste (from fuel reprocessing) will be disposed of underground.

High Level Waste (HLW): sufficiently radioactive to require both shielding and cooling, generates more than 2 kW/m^3 of heat and has a high level of long-lived alpha-emitting isotopes. HLW arise from the "burning" of uranium fuel in a nuclear reactor. HLW contains the fission products and transuranic elements generated in the reactor core. It is highly radioactive and hot, so requires cooling and shielding. It can be considered as the "ash" from "burning" uranium. HLW accounts for over 95% of the total radioactivity produced in the process of electricity generation. There are two distinct kinds of HLW:

- used fuel itself in fuel rods, or
- separated waste from reprocessing the used fuel as described below. HLW has both long-lived and short-lived components, depending on the time duration it will take for the radioactivity of particular radionuclides to decrease to levels that are considered no longer hazardous for people and the surrounding environment. If generally short-lived fission products can be separated from long-lived actinides, this distinction becomes important in management and disposal of HLW [2].

Waste management and sustainable development

In view of a sustainable development there are different waste management practices. One of this is the reprocessing. The main reason for reprocessing used fuel is to recover unused uranium and plutonium in the used fuel elements and thereby to close the fuel cycle, gaining some 25% more energy from the original uranium in the process and thus contributing to energy security. A secondary reason is to reduce the volume of material to be disposed of as high-level waste to about one fifth. In addition, the level of radioactivity in such 'light' waste is much smaller and, after about 100 years, it falls much more rapidly than in used fuel itself.
If the used fuel is reprocessed HLW, it comprises highly-radioactive fission products and some transuranic elements with long-lived radioactivity. These are separated from the spent fuel, enabling the uranium and plutonium to be recycled. The remaining HLW generates a considerable amount of heat and requires cooling. It is vitrified into borosilicate (Pyrex) glass, encapsulated into heavy stainless steel cylinders about 1.3 meters high and stored for eventual disposal of deep underground. This material has no conceivable future use and is unequivocally waste. The hulls and end-fittings of the reprocessed fuel assemblies are compacted, to reduce volume, and usually incorporated into cement prior to disposal as ILW.
This policy of transmutation is driven by two factors: reducing the long-term radioactivity in high-level wastes, and reducing the possibility of plutonium being diverted from civil use, i.e. increasing proliferation resistance of the fuel cycle. Reprocessing used fuel to recover uranium and plutonium avoids the wastage of a valuable resource. Most of it - about 96% - is uranium at less than 1% U-235 (often 0.4 - 0.8%), and up to 1% is plutonium. Both can be recycled as fresh fuel, saving up to 30% of the natural uranium otherwise required [3] .
For the future, the focus is on removing the actinides from the final waste and burning them with the recycled uranium and plutonium in fast neutron reactors. The longer-lived fission products may also be separated from the waste and transmuted in some other way. The objective of transmutation is to change (long-lived) actinides into fission products and successively long-lived fission products into significantly shorter-lived nuclides. The goal is to have wastes which become radiologically innocuous in only a few hundred years. Transmutation of one radionuclide into another is achieved by neutron bombardment in a nuclear reactor or accelerator-driven devices. In the latter, a high-energy proton beam hitting a heavy metal target produces a shower of neutrons by spallation. The neutrons can cause fission in a subcritical fuel assembly, but unlike a conventional reactor, fission ceases when the accelerator is turned off. Generally, short-lived ILW's (mainly from decommissioning reactors, are buried, while long-lived ILW's (from fuel reprocessing) will be disposed of deep underground. LLW's are disposed of in shallow burial sites. Then the products of transmutation are able to be buried.
In view of a sustainable development nuclear waste management costs have to be calculated. According to the criteria reported in ref. [4], for the Swedish program of nuclear plants decommissioning, in the year 2004 nuclear waste management cost was reported about 0,79 Euros / kWh. In U.S the waste management cost was estimated comparable, although a bit smaller. Calculation does not take into account the cost of power electricity or the amount of energy produced per ton of fuel.
All these costs included, a detailed cost-benefit balance has to be done, in order to decide what is the optimum percentage of the total amount of energy required for a sustainable development, to be produced in nuclear plants which use nuclear fission reactions.

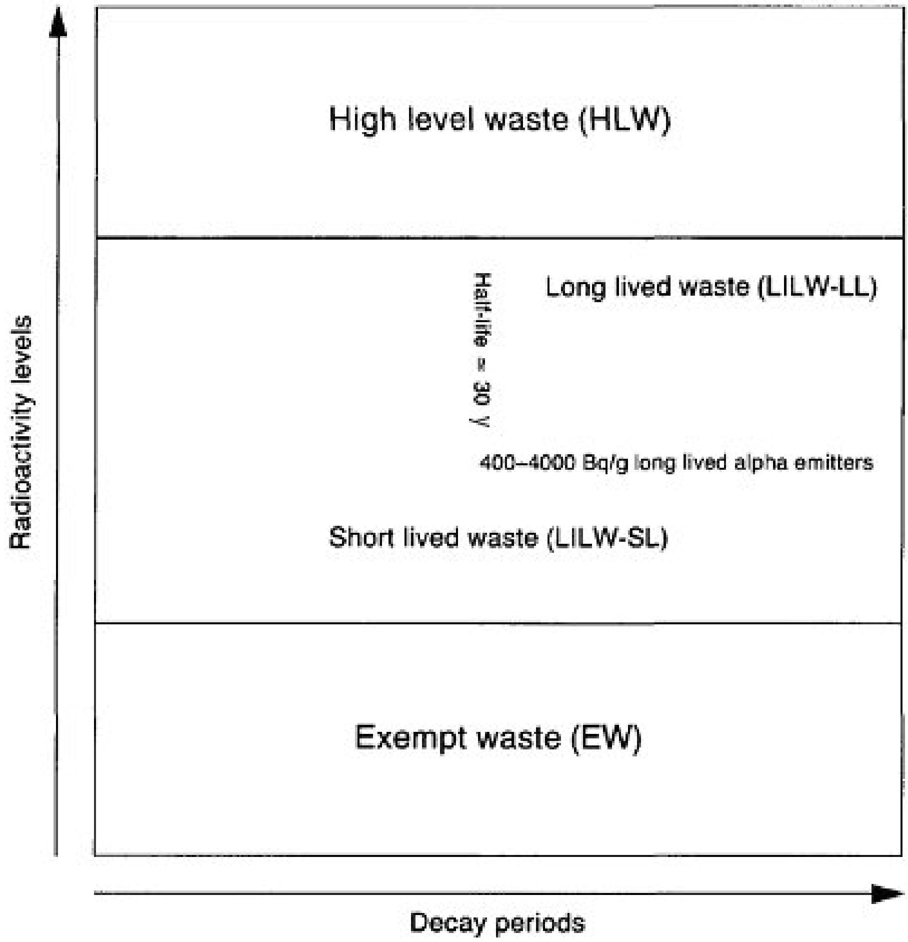

Fig. 1.Classification of radioactive waste

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Public Participation, Risk Perception and Stakeholder Involvement in View of Sustainable Development

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Abstract
The basic concept of sustainable development according to public participation, risk perception and stakeholder involvement is discussed in this paper.

Historically, on the view of the public, nuclear energy was surrounded by an atmosphere of secrecy. Nuclear technology was often associated with military purposes and the silence from the industry was universal and complete. To gain public support, nuclear industry must strive for an open and transparent management of the industry. It is important that there should be a deep level of trust between the industry, acting under strict regulatory controls and the public who relies on these controls. This leads to the immediate conclusion that the nuclear industry needs to focus on and continually search for the ways to build trust.

Nuclear power as an issue has lacked ‘salience’ for the public at large, in that people have been responding in a context where there has been little meaningful public or political focus on the issue. Recent government statements about climate change and the associated need for fresh energy investments may be changing this – which could explain the signals that a minority of perceptions of nuclear power may have been moving in a somewhat more positive direction.

Another instrument to regain public confidence is to articulate the benefits of nuclear science and technology as a whole. If there were no recognized benefits, the tolerance of the public for any risk will be exceptionally small. For example the nuclear industry needs to introduce the economic and environmental benefits. Whether or not specific public concerns have a valid scientific basis, they should be addressed directly, objectively, and informatively.

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. [2]

Hazard	Morality Risk/person/year
Cancer (all types)	$1.6x10^{-3}$
Auto accident	$2.8x\ 10^{-4}$
Drowning	$3.7x10^{-5}$
Cancer (Medical X-rays)	$1x10^{-5}$
Chocking on food	$5x10^{-6}$
Poisoning	$1.2x10^{-6}$
Living near nuclear power plant	$1x10^{-6}$
Lightning Strike	$8x10^{-7}$
Natural catasrophe	$6x10^{-7}$

Table 1. Some Mortality Risk Statistics in USA

Nuclear power reactors, with their enormous inventories of fission products, obviously carry the potential for major accidents involving many people. The risk may be perceived to be very high, 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. As an example, the studies in Korea [3] have shown that, both nationally and locally, people having a college education are about 1.2 times more likely to accept nuclear energy than persons having a middle school education.
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.
- Centralized 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 recognized 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).

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. 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.

Stakeholder involment in nuclear safety issues requires established communication mechanisms and venues for discussions between the interested parties. It is important to develop a common understanding of stakeholder roles and responsibilities, to distinguish clearly between scientific knowledge and social judgment, and to foster an atmosphere of mutual learning.

The experience of the past two decades shows that the growth of nuclear power is totally dependent on the favor of the public opinion. The nuclear industry has to make sure that they operate the facilities safely, meanwhile do all these as transparent and open as possible. The nuclear industry needs to use a language that the people can understand, so these messages show that the nuclear industry is acting responsibly. [1]

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Fissile resources and nuclear energy development scenarios in view of sustainable development

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Uranium resources

There are many Uranium resources, the Identified Resources, consist of Reasonably Assured Resources and Inferred Resources at a reasonable cost, in those values, can be significant changes, the most in the last years were in countries like Australia, China, Canada, Russia or South Africa.
We can identify different types depending on the type of extraction, i.e open pit, co product, in-situ leaching, or unspecified. Low-cost Uranium is based on co-products by mining in countries like Australia or South Africa underground mining and a little in situ leaching,(very important to consider future production), normal-costs U is expected to be produced by underground or open-pit mining.
There are also **undiscovered resources**, this refer to resources that are expected to occur based on geological knowledge of previously discovered deposits or regional maps, it require important amounts of exploration before the confirmation, there are only 26 countries with resources in this category.

Other

There are uncontional uranium resources like uranium in phosphate rock, or seawater and black shale (An additional 4.6 billion tons of **uranium** are estimated to be in **seawater).** The world average uranium content in phosphate rock is estimated at 50 - 200 ppm. Marine phosphorite deposits contain averages of 6 - 120 ppm, and organic phosphorite deposits up to 600 ppm, there are plants for the recovery of uranium from phosphoric acid in USA, Canada, Spain, Belgium, Israel, and Taiwan. Historical operating costs for the uranium recovery from phosphoric acid range from 22 to 54 US$/lb U_3O_8. These operating costs are by far higher than past uranium market prices, and most uranium recovery plants have been closed, therefore. In view of the recent increase of the uranium market price, the situation may change, again.

Thorium

Thorium, as well as uranium, can be used as a nuclear fuel. Although not fissile itself, thorium-232 (Th-232) will absorb slow neutrons to produce U-233, which is fissile and long-lived. Hence like U-238 it is fertile. Over the last 30 years there has been interest in utilising thorium as a nuclear fuel since it is more abundant in the Earth's crust than uranium. Also, all of the mined thorium is potentially useable in a reactor, compared with the 0.7% of natural uranium, so some 40 times the amount of energy per unit mass might theoretically be available (without recourse to fast breeder reactors).

Current commercial capacity and related uranium requirements

World: On the first of 2007, in 30 countries a total of 435 commercial nuclear reactors were operating and over 27 reactors were under construction. World annual uranium requirements amounted to 66500 tU in 2006 and are estimated to increase to about 69110 tU in 2007.
OECD: At the beginning of 2007, in 17 OECD countries there were 343 reactors in operation (83% of the world's nuclear electricity generating capacity). The OECD reactor-related uranium requirements were 56625 tU for 2006 and are expected to increase to 57690 tU in 2007.

Projected capacity and related uranium requirements to 2030

Uranium demand is also directly influenced by changes in the performance of installed nuclear power plants and fuel cycle facilities, even if the installed base capacity remains the same. There are other factors that affect uranium requirements include plant retirements, fuel-cycle length and discharge burn up and the strategies employed to optimise the relationship between enrichment services and the price of natural uranium. Nuclear phase-out programmes currently in place en several European nations will tend to reduce installed capacity over time in that region. However, constructions programmes, particularity in east and central Asia, along with capacity is expected to continue to increase through 2030, thereby increasing projected uranium requirements.

Projections to 2030

Forecasts of installed capacity and uranium requirements, although uncertain due to the above mentioned factors, point to future growth. Figure 1 y figure 2

Uranium exploration

A very significant increase in exploration and development activities occurred in 2005 and 2006 driven by increases in the uranium spot price. These activities were conducted in countries which explored and developed uranium deposits in the past and also in many countries exploration for uranium had not been conducted for many decades. Since most of these countries did not report these activities, total worldwide uranium explorations are likely higher than what is reported.

Worldwide uranium exploration continues being concentrated in areas considered to have the best likelihood for the discovery of econimically attractive deposits, mainly unconformity-related, sandstone-type and hematite breccia complex deposits.

Uranium production

In 2007, uranium was produced in 20 different countries; one more than in 2004 as the Islamic Republic of Iran started production in 2006. However, three of these 20 countries (France, Germany and Hungary) only produced uranium as a consequence of mine remediation efforts. Two countries, Canada and Australia, accounted for 44% of world producction in 2006 and just eight countries, Canada (25%), Australia (19%), Kazakhstan (13%), Niger (9%), the Russian Federation (8%), Namibia (8%), Uzbekistan (6%) and the Unites States (5%), accounted for about 93% of word production in 2007.

Production methods: Uranium is mainly produced using open-pit and underground minig techniques processed by conventional uranium milling. Other methods include *in situ* leaching (ISL); co- or by product recovery from copper, gold and phosphate operations; heap leaching and in-place leaching.

Long-term perspective

Uranium demand is driven by capacity of operating and projected nuclear reactors. As world demand for electricity is expected to increase, an increasing of nuclear energy demand is expected too. Nuclear energy should be seen as beneficial in meeting greenhouse reduction targets, using it instead of fossil fuels. Nuclear energy can not only substitute fuel fossils at electricity production, but also in transportation. High temperature reactors underdevelopment could be used in hydrogen generation in a more efficient way than currently electrolysis methods.

Another factor in uranium demand is the initiatives that some governs and the IAEA are taking, concerning a closed fuel cycle and the establishment of multilateral enrichment and fuel supply centers. The expected technological advancements would also concern an increase of the efficiency with which uranium is utilized. New and advanced reactors designs will allow the use of materials like uranium-238 and thorium, as nuclear fuel.

To conclude, uranium demand for electricity generation in the log-term is guaranteed by Identified Resources for over 80 years, considering 2006 uranium requirements. Or even for about 100 years considering a more realistic approach. And if the entire Conventional Resources are exploited this estimation would increase to about 300 years. There is considerable potential for discovery of new resources of economic interest. Recycling fuel and moving to advanced technology reactors that use thorium as fuel, could increase the long-term availability of nuclear energy to thousands of years.

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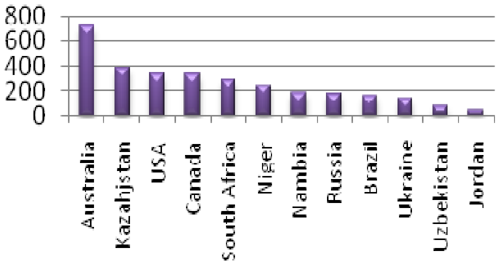
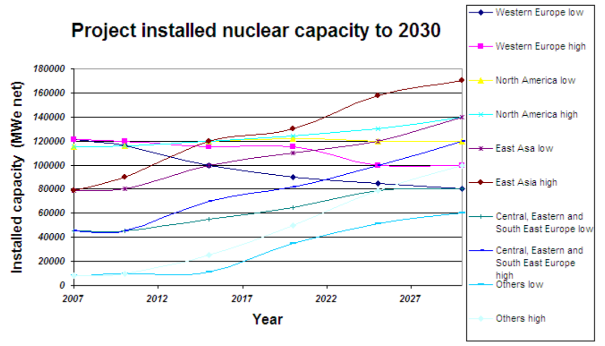
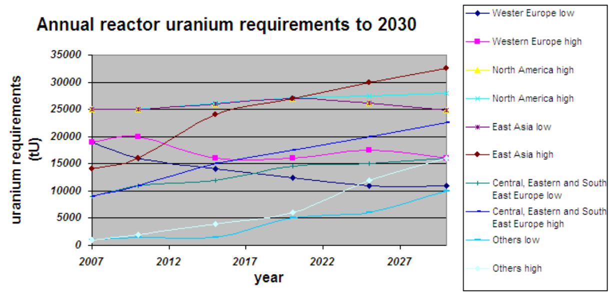
Distribution of Reasonably Assured Resources among countries

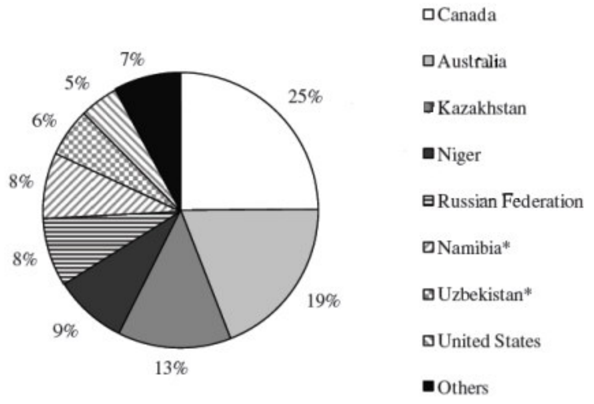






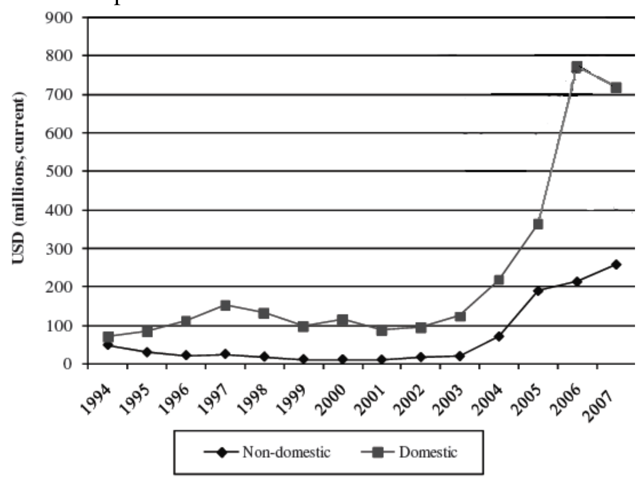
Approximate uranium inventories in phosphate deposits	
Country	**million t U**
Marine phosphorite	
Morocco	6.9
USA	1.2
Mexico	0.15
Jordan	0.1
Others	0.65
Subtotal	*9*
Organic phosphorite	
Kazakhstan Russia (both)	0.12
Subtotal	*0.12*
Total	9.12

Trend in exploration and development expendidures.



Estimated World thorium resources (RAR + Inferred to USD 80/kg Th):		
Country	*Tonnes*	*% of world*
Australia	452 000	18
USA	400 000	16
Turkey	344 000	13
India	319 000	12
Venezuela	300 000	12
Brazil	302 000	12
Norway	132 000	5
Egypt	100 000	4
Russia	75 000	3
Greenland	54 000	2
Canada	44 000	2
South Africa	18 000	1
Other countries	33 000	1
World total	2 573 000	

Uramium production



New generation project and non-energy applications (heat generation, hydrogen production, …) in view of sustainable development

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Abstract

The concept of sustainable development first became recognized in 1980 when the International Union for the Conservation of Nature published the World Conservation Strategy. Since then, the term has become commonplace and many new things has been added to this basic concept. This article seeks to identify some of the new generation projects and their non-energy application - namely Heat Generation, Hydrogen production, Transportation and Waste reduction - in view of sustainable development.

Heat generation

The core element of a district heating system is usually a cogeneration plant (also called combined heat and power) or a heat-only boiler station. Both have in common that they are typically based on combustion of primary energy carriers. The difference between the two systems is that, in a cogeneration plant, heat and electricity are generated simultaneously, whereas in heat-only boiler stations - as the name suggests - only heat is generated.

The combination of cogeneration and district heating is very energy efficient. A thermal power station which generates only electricity can convert less than approximately 50 % of the fuel input into electricity. The major part of the energy is wasted in form of heat and dissipated to the environment. A cogeneration plant recovers that heat and can reach total energy efficiency beyond 90 %. Climate change is one of the challenges to sustainable development. In this context, cogeneration plant is much more environmentally friendly.

Heat sources for district heating systems can be geothermal heat, solar power, surplus heat from industrial processes or, of course nuclear power too.

On the other hand, next possibility is that each house has its own heating generator and heat is distributed only in that house. This situation is very frequent especially in small towns and villages. Of course, this solution is burdensome environment in comparison with centralized heating generator.

Hydrogen production

Hydrogen, the most abundant element in the universe, is to be considered, as a fuel, clean, powerful, renewable, and environmentally benign. It can be burnt to water vapor releasing its chemical energy as heat and stored directly or transported for later usage. The introduction of hydrogen as a significant contributor to meet the world's energy demand in the future requires infrastructures, economic issues and markets, and last but not least, safety issues.

Hydrogen is commonly produced by extraction from hydrocarbon fossil fuels via a chemical path. Hydrogen may also be extracted from water via biological production in an algae bioreactor, or using electricity (by electrolysis), chemicals (by chemical reduction) or heat (by thermolysis); these methods are less developed for bulk generation in comparison to chemical paths derived from hydrocarbons.

There is also the possibility to produce hydrogen in Generation IV nuclear reactors. One side benefit of a nuclear reactor that produces both electricity and hydrogen is that it can shift production between the two. For instance, the plant might produce electricity during the day and hydrogen at night, matching its electrical generation profile to the daily variation in demand. If the hydrogen can be produced economically, this scheme would compete favorably with grid energy storage schemes.

The high temperatures necessary to split water can be achieved through the concentration of Solar energy. Scientists at the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) set up a 100-kilowatt pilot plant which uses sunlight to obtain the required 800 to 1,200 degrees Celsius to split water. The design of this 100-kilowatt pilot plant is based on a modular concept. As a result, it may be possible that this technology could be readily scaled up to the megawatt range by multiplying the available reactor units and by connecting the plant to heliostat fields (fields of sun-tracking mirrors) of a suitable size.

Transportation

Public transport comprises passenger transportation services which are available for use by the general public, as opposed to modes for private use such as automobiles or vehicles for hire. Some services are free though most charge some sort of fare.

Public transportation can consist of buses, subways, trolleys and light rail, commuter trains, van pool services, paratransit services for senior citizens and people with disabilities, ferries, and so on. Each of the listed means of transport has its pros and cons and each of them, of course, has another impact on environmental sustainability, economic sustainability, and social-political sustainability. For example, studies have shown that there is a strong inverse correlation between urban population density and energy consumption per capita, and that public transport could play a key role in increasing urban population densities, and thus reduce travel distances and fossil fuel consumption.

An important social role played by public transport is to ensure that all members of society are able to travel, not just those with a driving license and access to an automobile - which include groups such as the young, the old, the poor, many medical conditions or people banned from driving. On the other hand, people with a license and car are often lazy and comfortable to travel by public transport. In this context is also question of fuel used for this or that means of transport. Each fuel has its positives and negatives, whether environmental or economic impacts.

Waste reduction

All the products you buy, or at least their packaging or containers, will eventually require disposal. Waste reduction refers to reducing the amount of waste produced (an example is using silverware instead of using plastic flatware) or also to reducing toxic substances in waste (an example is using a nontoxic oven cleaner instead of one that contains hazardous ingredients).

Waste reduction starts at the shopping centre. If you want to reduce waste, your preferences would be for example: buying durable products instead of those that are disposable or cheaply made, repairing/restoring used items before replacing them, buying items you can re-use, buying items you can recycle locally through curb side collection or recycling centres, and so on.

Separate and extensive topic for discussion is undoubtedly the radioactive waste and its processing. About radioactive waste in short in the following lines. Radioactive wastes are waste types containing radioactive chemical elements that do not have a practical purpose. They are usually the products of nuclear processes, such as nuclear fission. However, industries not directly connected to the nuclear industry may produce large quantities of radioactive waste. The majority of radioactive waste is "low-level waste", meaning it contains low levels of radioactivity per mass or volume. This type of waste often consists of used protective clothing, which is only slightly contaminated but still dangerous in case of radioactive contamination of a human body through ingestion, inhalation, absorption, or injection.

The question of the future fate of spent nuclear fuel is one of the major and most pressing problems that the current energy concerns, in the Czech Republic too. Today we basically offer, as was mentioned, two alternatives: either be placed in the final repository, or slightly more expensive option is to further revisions. Until the Czech Republic will decide which of these are issued, their nuclear waste will be placed in the intermediate containers for 40 to 50 years.

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Passive Safety Systems in view of Sustainable Development

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Abstract

This paper presents the aspects of sustainable development used in current and new type reactors (IRIS and AP1000). In particular it is shown the technical aspects of the Passive Safety Systems (PSS) involved in the plant and how they are related to the sustainability features. The most interesting characteristics regard intrinsecal security, economical costs and public acceptance.

1. Introduction

Traditional reactor safety systems are active: they are based on external actions, such as intelligent electronic signals and human operational intervention.
In the last years technologists and project engineers developed new types of safety systems: they guarantee an high security level without the presence of active ones. By this point of view, if the accident occurs, Passive Safety Systems (PSS) will naturally work, because they depend only on physical phenomena, such as pressure differential, convection, gravity, or the natural response of materials to high temperature to slow or shut down the reaction.

2. Types and Sustainability of PSS

International Atomic Energy Agency (IAEA) divides PSS in three main categories with a decreasing level of passivity [[1]]:

1. Completely static (e.g.: thermal irradiation through two surfaces).
2. Moving working fluids (e.g.: through natural convection).
3. Moving working fluids and mechanical parts (e.g.: fluid injection with the opening of unidirectional valve).

PSS provide plant safety and protect capital investment because they own these main caracteristics to fulfill the objective of sustainability [[2]]:

- Intrinsical security: they establish and maintain core cooling and cointanment integrity indefinitely, with no operator or AC power support requirements.
- Economical costs: primarily the PSS fulfils the single-failure criteria and Probabilistic Risk Assessments (PRA) used to verify reliability; the PSS are significantly simpler than typical PWR safety systems and they need fewer number of redundancies, maintenances, inspections and controls than a traditional system. Secondly the PSS can avoid false alerts and consequently the economical damage based on loss due to the shutting down of the plant.
- Public acceptance: the more simplicity, the fewer dimensions, the more intrinsecal and passive security of these new solutions are elements useful to project valid engineering products that have the aim to let society comprehend and accept the nuclear energy.

3. Examples of passive safety in operation

The Pebble Bed Reactor (PBR) is an example of a passively-safe reactor: when the temperature of the fuel rises, Doppler broadening increases the probability that neutrons are captured by ^{238}U, reducing the reactor's power output and placing an inherent upper limit on the temperature of the fuel [[3]].
In current Light Water Reactors (LWRs), in the event of an excessive-power condition, steam pockets voids moderate fewer neutrons, causing the power level inside the reactor to lower.
If pool Fast Breeder Reactors (FBRs) overheat, thermal expansion of the metallic fuel and cladding causes more neutrons to escape the core, and the nuclear chain reaction can no longer be sustained. The

large mass of liquid metal also acts as a heatsink capable of absorbing the decay heat from the core, even if the normal cooling systems would fail.

4. The sustainability of PSS in new types of reactors

4.1. IRIS

IRIS (International Reactor Innovative and Secure) [4] [5] is an integrated, innovative and modular PWR. Its schematic representation is presented in Fig. 1.
Between its aims, IRIS wants to reach an higher level of safety. This objective is pursued by the adoption of PSS and by the engeneering choise of "Safety by Design":

- All the main primary system components are located inside the vessel, so there's no possibility to have a LOCA accident.
- The 8 adopted steam generators have a once-through, helical-coil tube boundle design, with the primary water that flows outside the tubes: as the primary fluid has a more pressure than the secondary one, the helical tubes are in compression, the tensile Stress Corrosion Cracking (SCC) is automatically eliminated. So, the probability of tube failure is greatly reduced, and, if it does occur, there's no plausible mechanism for a failure propagation.
- IRIS defence-in-depht foresees also a mitigation of the consequences in case of small-breaks LOCAs through the use of PSS.

These characteristics regard the aspect of "intrinsecal security", as they eliminate "by design" the eventuality of severe accidents (such as LOCA) or mitigate the common ones (such as SCC).
Moreover, IRIS has this interesting peculiarity: with an enrichment in ^{235}U of 5%, the reactor core can operate continously for 4 years. So, the time interval between programmed maintenances has to be increased to 48 months (15 months for traditional PWRs). So, the primary system components are designed to have very high reliability to decrease the incidence of failures and reduce the numbers of inspections and repairs. This characteristic regard the aspect of "economical costs", as IRIS is more reliable and can operate for more time without shutting down the reactor. All the passive safety aspects are summarized in Table 1. As with IRIS the accidents that can cause radioactive releases are eliminated by design or they have much less probability to occur and lead to much more mitigated consequences than a traditional PWR, IRIS increases the public acceptance of nuclear energy.

4.2. AP1000

Simplicity is a key technical concept behind the AP1000 plant [6]. It makes the AP1000 easier and less expensive to build, operate and maintain. Its schematic representation is presented in Fig. 2.
Two model Delta-125 steam generators are used, with the highest level of reliability achieved by any steam generator worldwide. Elimination of the pump shaft seals greatly simplifies the auxiliary fluid systems, eliminates planned maintenance, possible accidents involving seal failures and the use of oil (and the potential for fires). The integration of the pump suction into the bottom of the steam generator channel head eliminates the crossover leg of coolant loop piping and so the potential for uncovering the core during a small LOCA.
The safety systems include passive safety injection, passive residual heat removal, and passive containment cooling. The passive core cooling systems (PXS) protects the plant against the Reactor Coolant System (RCS) leaks and ruptures, it provides core residual heat removal, safety injection, and depressurization.
The AP1000 plant costs and construction schedules benefit directly from the great simplifications provided by the design. There are 60% fewer valves, 75% less piping, 80% less control cable, 35% fewer pumps, and 50% less sismic building volume than in a conventional reactor.
The components minor costs and the higher level of reliability allow to reach a major grade of sustainability, both by the economical side and by the plant intrinsecal security.

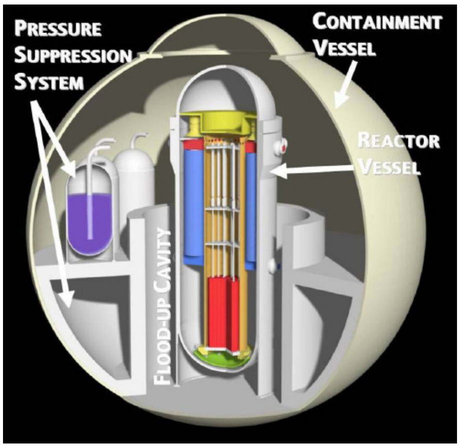

Fig. 1. The new reactor IRIS.

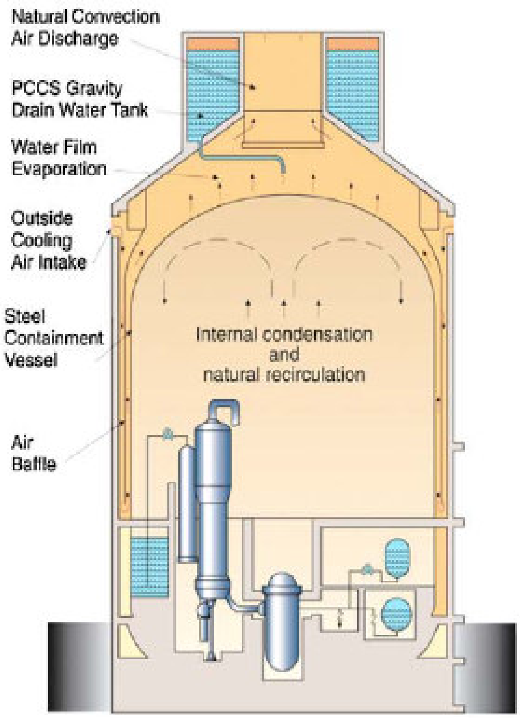

Fig. 2. The new reactor AP1000.

IRIS Design Characteristics	Safety Implications	Mitigated accidents
Integral layout	No large primary piping	-LOCA
Large, tall vessel	-Increased water inventory -Accomodates the Control Rod Drive Mechanism.	-LOCA -Control Rods ejection, elimination of heads penetrations.
Heat removal from the vessel	-Depressurizes primary systems by condensation -Heat removal from EHTS	-LOCA -LOCA -ATWS

		-Event that requires cooldown
Reduced size, higher design-pressure containement	Reduced driving force through primary opening	-LOCA
Multiple coolant pumps	Decrease importance of single pump failure	-Pump break
High design-pressure steam generators system	-No steam generators safety valves -Primary system cannot overpressure secondary one -Reduction piping failure probability	-Steam generator tube rupture -Steam line break -Feed line break
Once-through steam generator	Limited water inventory	-Steam line break
Integral pressurizer	Large pressurizer volume/reactor power	-Overheating events -ATWS

Table 1. Implications of Safety-by-design approach of IRIS reactor.

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Report of the final round table discussion

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Sustainable development is defined as: 'a development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland Report). Shortly, it can be said that sustainable development has three main components: social, economical and environmental. As there are no optimal solutions, trade-offs between these components are required, and options for energy production should take into account each of these components. This also applies to the energy problem.

We came to the conclusion that presently we face three main problems regarding the energy production: pollution due to fuel based energies, an increase of energy consumption and the present inability in increasing the efficiency of energy production methods presently used. Renewable energy sources alone are not the solution for these problems. Nuclear energy was concluded to be part of the solution for a sustainable development, at least presently.

However, public perception tends to see renewable energy sources as completely harmless and nuclear energy sources as unsafe. The reasons for this situation are due to the memory of nuclear accidents (Chernobyl) and a manipulation of public concerns by media. The lack of trust in political leaders and the distance between scientific community and common people were also identified as obstacles to the acceptance of this solution by the public. Thus, it was pointed out that it is of prime importance to prepare public opinion to accept nuclear energy since it can be part of a sustainable development solution.

There are two things that can be done to change people's minds about this: try to acquaint students from secondary school with nuclear energy production and try to make TV spots to inform people addressing their concerns about nuclear power plants, since television is an easy way to reach a vast part of the population.

One of public concerns is the nuclear waste produced as a result of fission. One solution presented is the long term storage of radioactive waste in clay layers, which would allow the digging of this material if science research could find a method to turn it into something useful, but send this waste to space does not seem to be an option since this material could collide with satellites or fall back to earth, producing a nuclear accident.

Another issue which has to be clarified to the public is what are the advantages of nuclear energy sources and in which situations the use of this kind of energy source can be more useful. In large cities as Paris, London or New York, the common citizen could save much money in the electricity bill, which would not be the case for suburban areas since a bigger distance between houses would increase energy losses by heat rendering this energy source economically inefficient.

There is also another thing that should be taken in consideration. Nowadays European countries are dependent of fuel they purchase abroad, nuclear energy could reduce the energetic dependence of our societies, enabling them to be more stable since this would allow a better control of energy prices.

Another thing that public opinion should be aware of is that, even if nuclear energy production is not a perfect solution in terms of sustainability, it allows our societies to gain time to find other solutions. There is no technological revolution in the horizon, like the one brought by the twentieth century, but the future is open and money should be spent in projects concerning other methods for obtaining energy, like nuclear fusion or improving renewable sources.

Hydrogen could be presented as a sustainable form of energy but this is not so because storage and transportation of this material is very difficult as this gas is flammable and needs to be stored under high pressure. Presently, its creation needs an input of energy superior to the energy that can be delivered (unless if there is a real possibility of generating this gas with a Gen IV reactor).

It was also emphasized that, since energy generation has an important place in our societies, the stability of this market should be assured. Therefore the governments should have a major role in preventing that market crashes perturb the energy production.

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CHERNE

Cooperation for Higher Education on Radiological and Nuclear Engineering

Erasmus Intensive Programme Project (IP)

ICARO

Intensive Course on Accelerator and Reactor Operation

01/03/09 – 14/03/09

– Lisboa, Portugal –

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Universitad Politecnica de Valencia, Valencia, Spain
XIOS Hogeschool Limburg, Diepenbeek, Belgium

Round tables

1. Nuclear and Sustainable Development

2. Ethics and the Principle of Justification – the case of Nuclear Technology Assessment –

– Annexes –

ICARO Round tables: practical introduction

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on behalf of the ICARO organising committee

Apart from lectures and practical experiments in the Erasmus Intensive Programme '*Intensive Course on Accelerator and Reactor Operation, ICARO*' [[1]], organised by the Cherne network [[2]], the programme will include student's papers, talks and presentations, and discussions.

Two round table discussions are foreseen:

1. Ethics and the Principle of Justification – the case of Nuclear Technology Assessment
2. Nuclear and sustainable development.

1. Ethics and the Principle of Justification – the case of Nuclear Technology Assessment

In the first round table the question will be asked:

- whether and how (we as) engineers can '*act in a responsible way*' in a real working environment, facing situations which are characterized by uncertainty and ambiguity
- how we can develop an '*ethical sense*' to confront such situations.

The philosophy of ethics and the discourse on ethics and technology will be introduced by a specialist who has already performed research in this field for many years, especially in the framework of nuclear technology (see separate abstract). The participants will then analyse some typical cases relevant for the nuclear engineer.

2. Nuclear and sustainable development

In the second round table the participants *themselves* will elaborate on some aspects of nuclear technology in view of sustainable development. In their working environment, but also as individual social and economical partners, engineers and scientists should have a valuable input into this debate, based on their competence and responsibility.

In order to get a fruitful and efficient discussion on sustainable development in the round table, the participants are expected to get familiar with the subject:

- by critically analysing the introductory paper on nuclear and sustainable development [[3]],
- by studying, elaborating and presenting their views on one of the chosen topics relevant for the discussion

The chosen topics are:

1. The concept of sustainable development in general and the implication for the energy sector in particular
2. Comparison of nuclear energy and alternatives in view of sustainable development (excluding competitiveness)
3. Assessment of competitiveness based on comparisons of full costs to society including social and environmental costs
4. Radioactive waste management (including partition and transmutation) in view of sustainable development
5. Public participation, risk perception and stakeholder involvement in view of sustainable development
6. Fissile resources and nuclear energy development scenarios in view of sustainable development
7. New generation projects and non-energy applications (heat generation, hydrogen production, …) in view of sustainable development
8. Passive safety systems in view of sustainable development
9. Energy efficiency as main resource for energy supply in view of sustainable development
10. Proliferation of nuclear weapons as a treat to peaceful nuclear development.

Subgroups of 3-4 participants are expected:

- to prepare before 01/02/09 a paper of maximum 2 pages (references and figures eventually extra) introducing their assigned topic (*following the layout presented separately* [[4]])
- to prepare a ppt-presentation of maximum 10 minutes for the round table. The ppt-file should be send in before 15/02/09.

The participants should not only play the role of the 'expert' presenting their own topic, but for the other topics also the roles of 'counter-expert' and of the 'public'. Therefore the abstracts will be distributed beforehand among the participants by email. On base of these abstracts each subgroup is expected to formulate before 22/02/09 two to three discussion points on each topic based on a critical analysis of the abstracts, as an input for the discussion at the round table.

As one of the inputs to the work expected from the participants the documents of the round table on sustainable development of the Erasmus IP Speransa in Belgium in 2008 are available [[5]]. The difference between the present round table and the previous one exists in the fact that the previous one focussed mainly on technological and engineering solutions, while the present one has to focus on the implications on sustainable development.

The first part of the programme of the round table will be a kind of symposium where most of the topics (except two) will be presented (10 min) followed by a discussion (5 min).

The second part of the programme will consist of the real round table discussion. The two remaining topics will be presented (10 min each) followed by an extended discussion among the participants (30 min each), and concluded by a general debate.

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[[5]] http://www.upv.es/cherne/icaro09.htm, in http://www.upv.es/cherne/

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Nuclear and Sustainable Development: discussion points

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1. Ethics and the Principle of Justification – the case of Nuclear Technology Assessment

- Which are the main means to let nuclear energy sustainable for a government?
- In our opinion, for a government is it ethic to take the decision to use the nuclear energy without listening to society?
- Is it ethical for the media to use the accidental history of nuclear power over and over again in the public?
- Are the methods used by the anti-nuclear groups ethical?
- Up to which level can the safety concerns of people about nuclear power are justified?

2. Nuclear and Sustainable Development: an Introduction

3. The Concept of Sustainable Development in General and the Implication for the Energy Sector in Particular

- Which of the three main aspects (economy, environment, society) is the most discussed argument for governments, societies, universities, researchers?
- Is any of the three elements of sustainable development (environmental, economical and social) inevitable?
- How social, environment and economic aspects meet the requirements of sustainable development in our society in the case of energy sector?
- Nowadays which of the three sustainability aspects (social, environment, economic) do we think has reached the lowest level?
- Are really environmental, social, and economic dimensions at the same level?
- Do we think that explaining the nuclear matter to the public in a simple way is sufficient to let the public itself understand and accept the nuclear energy?
- Are there any objections against the concept of sustainable development?
- What is the place of nuclear energy among the other energy types in terms of sustainable development?
- Can we make an example of the sustainability indicators?
- Talking about social sustainability, which is the influence of the policy in the energy choice for a country?
- Are there some methodologies that indicate the progress of energy technologies in a sustainable contest?
- Is it better to break an equilibrium at the lack of energy at the expense of environment or try to reduce an energy consumption?
- More money should be invested into sustainable development?
- Is it necessary to keep all energy options open?
- How can we integrate economic growth, environmental protection and social welfare?
- What will be the results of extending the benefits of energy supply to the whole world?
- The definition of 'sustainable development' is large and it can be interpreted in several ways. So now we can ask ourselves: is it possible to observe the definition of sustainable development? Or are there too many short cuts provided in the definition so we can also escape from the real pressure points?
- 'Energy has a direct impact on poverty and the standard of living'. Shall this impact change in the future when all the energy resources are environment-friendly/comply with the definition

of sustainable development?

4. **Comparison of nuclear energy and alternatives in view of sustainable development (excluding competitiveness)**

- Which energy type meets the requirements of sustainable development more effectively?
- How long can we keep using fossil fuels as one of the main sources of energy production?
- Can renewable energies compete with nuclear in the future in the view of sustainable development?
- Is sustainable development, as stated in the definition, possible?
- Is nuclear energy a likely candidate?
- Is a global solution possible or will several types of energy resources solve the energy problem?
- Is it well-considered to ignore all ethical side effects (e.g. starvation caused by decreasing agricultural area, disturbance of fauna and flora) to satisfy energy needs.
- Should the solution come from technology or society (changing way of life)?
- The solutions for the future in view of sustainable development (generation IV, fusion nuclear): how can they solve the problems and mitigate the difference to reach a sort of sustainable development?
- Is it possible to maintain together a great development of both nuclear plants and solar (renewable) energy systems?
- Focusing on the energy resources that use commodities, why should they be avoided for a sustainable development?
- Do we think that is better for a sustainable development to have a mix of energy technologies in order to 'share' the problems connected to the production?
- Is it clever to try to close nuclear plants and rely on progress in alternative sources?
- Can nuclear energy fully replace fossil fuels at present?
- And what about gas power plant? Can they supply enough energy? Dependence on Russian gas?
- Is really nuclear waste the most criticized form of waste?
- Nuclear waste versus greenhouse gas emissions, which will be limit of the choice between the two environmental problems?

5. **Assessment of competitiveness based on comparison of full costs to society including social and environmental costs**

- Which costs matters in market price of electricity that provided by Nuclear Power Plants?
- Which economic conditions should be provided to build a Nuclear Power Plant?
- The high capital cost is one of the most important economical aspects of nuclear power. How is it possible to reduce that term in order to let nuclear power be more sustainable in view of economical aspect?
- How are going to change the other (not nuclear) energy systems costs in the future?
- How can we pass from the CO2 emissions data to the economical parameter "external cost" associated to them?
- Why is solar energy so promoted, when costs are so high and without dotations is this project hardly practicable?
- If the whole world would be going nuclear, what with the exhaustibility of the nuclear resources?
- Is it practical to increase rate of alternative sources of energy to 20% in 2020 according to demand of EU and is it economically available?
- Power sources should be supported (by government)? Which ones?
- If nuclear power is the solution to reduce carbon dioxide emissions, won't upcoming economies or third world countries still choose for low cost investments like fossil fuel plants?
- Should emission costs for carbon dioxide be raised to make fossil fuels less attractive?

- When fossil fuels become very scarce, won't the prices for uranium also increase to very high levels which will raise the total costs for nuclear power?
- What are the criteria to determine the damage costs due to global warming, as presented in €cent/kWh. How is it accounted for?

6. Radioactive Waste Management in view of Sustainable Development

- Which methods are used to reduce the volume of wastes?
- What do we think about the space used for nuclear wastes?
- How does society deal with important social issues involving scientific and technical problems in nuclear wastes?
- Which level of risk can be considered trustworthy for radioactive waste management in the next future?
- Which kind of approach has to be taken with the population near the waste deposit site? Which kind of benefits should be given to balance the waste fear?
- Do we think that reprocessing choise is more sustainable than the "once-through" solution or not? And why?
- How much can a long-term disposal be safe in a long future considering geological events (seismic, volcanic, ..etc) and social events (war, terrorism, etc)?
- In general it is very difficult for the population to accept a nuclear disposal. How can it be resolved? More information?
- Is it right to deposit radioactive waste and problems with its disposal give up to other generations?
- Is it better storage or transmutation of the radioactive waste?
- Is preferable to monitor the problem of radioactive waste at the national or international level
- In view of sustainable development in a very strict way, isn't every energy production against this principle?
- In the future, what will be the biggest threat? Nuclear waste, properly stored for thousands of years with the risk of accidents or disasters, or the greenhouse gasses?
- Does every country have the possibility to store their own nuclear waste in a safe way or should it be possible to have free market for nuclear waste between governments?

7. Public Participation, Risk Perception and Stakeholder Involvement in View of Sustainable Development

- Is risk perception the main problem for the development of energy resources?
- Is stakeholder involvement the solution for the development of energy resources?
- What does stakeholder involvement means in practice?
- Population is sensible about nuclear energy. In which ways is it possible to act in order to guarantee security and reliability?
- Would it be useful to teach the basic principles of nuclear energy already in the primary schools?
- It is said that public acceptance will increase if there's a responsible controlling authority. How the controlling authority independence is guaranteed?
- In our opinion in Europe, how much is the memory of the Chernobyl accident alive?
- Do we have some ideas where and which programs a country have to follow to give scientific knowledge to the population?
- Can visits, meetings and discussions with public increase credit of nuclear energy or are they easy influenceable and trust very much mass media?
- Is public participation dangerous in view of terrorism? Terrorist attack?
- Is it right to let public to decide about nuclear energy in referendum or rely on politicians?
- There is often no direct communication between the nuclear sector and the public at large. Trust by the public will be influenced by the opinion of the political world or the media. It should be the other way round. How can we manage that? Are there independent institutions to start the dialogue?

- Nuclear energy has indeed al lot of benefits, but how do we compare these with regard to the benefits of other technologies. How can we measure benefits? Isn't it a very subjective matter?

8. Fissile resources and nuclear energy development scenarios in view of sustainable development

- Why most of countries avoid reporting their uranium explorations?
- Is it plausible to share the big amount of uranium production between two countries? Will it cause later on lack of Uranium? Should it be concerned alternative fuel types?
- As a comparison on fuel cost per power generation, which selection is in favor of operating PSS based on Uranium or Molten Salt Reactor based on Thorium?
- Uranium and Thorium are the main resources for nuclear plant. How long can fuel last with new generation of nuclear reactors (III and IV)? Is it possible to reach an ideal utiliziation of fuel with the new technological discovers?
- How can it be explained to the public that Uranium is better than oil if they are both going to be carried out in about 100 years?
- Adopting the Th-cycle, the nuclear fuel can last thousands of years: but thinking to the difficulties of this type of cycle (remote handling of fuel also before the reactor burning), what's about the sustainability of this choice?
- In a long-term prospective is the nuclear energy sustainable if the Generation IV Reactors will not be developed?
- Uranium mines are present only in some countries in the world. Can these countries have a restricted monopoly and a control of the cost, like the petroleum situation?
- Should we continue in construction current types of reactors or more likely invest in development of new types such as fast breeder reactors or reactors of 4.generation?
- And what about nuclear fusion? It nuclear fusion source of the future?
- Is it better to divide up the production of uranium (or another fissile material for nuclear power plants) to more countries, or concentrate in one or two countries?
- It seems there are more uranium resources than we know, but the question remains, is it technological and economical possible to use all these available uranium resources?
- Isn’t it a little euphemistic to make estimates of uranium availabilities on grounds of technologies which not yet exists? For instance technological advancements like close fuel cycles, operational generation IV reactors, etc.
- How and where can uranium be extracted in Europe and how can it determine the energetic independence of Europe?

9. New generation project and non-energy applications (heat generation, hydrogen production, transportation) in view of sustainable development

- What are the advantages and disadvantages about using nuclear power to generate heat in houses?
- As discussion is on hydrogen production and transportation, what is our opinion about hydrogen production in fourth generation reactors and usage of hydrogen internal combustion engine vehicle (HICEV)?
- A cogeneration plant is the most used way to reach a sustainable development, in particular about environmental aspect. In which fields (industrial and not) is it possible to use this type of solutions and how?
- How can government help to succeed in reducing waste and to improve people social behaviour (taxes, incentives)?
- Can we make an example that let us understand how the H production and use can lead to a sustainable future development?
- In our opinion, looking on the two solution mentioned for the disposal of spent fuel, what is the better way for safety and public acceptance?
- Can the hydrogen-based technology be economically attractive compared to oil and gas based technology?

- Is heat generation economically viable? One has to transport the heat to all the homes, so there is must be much heat loss during transportation.
- Is transportation of hydrogen safe? It is a highly flammable product and it is stored under enormous pressure.

10. Passive Safety Systems in view of Sustainable Development

- In IRIS pressurizer is not contained in a separate vessel and connected to the primary side, but rather is the top of the pressure vessel itself. What are its benefits?
- How is once through steam generators in IRIS operational conditions dealt with supercritical conditions which causes problems such as purity of feed water?
- According to the paper, IRIS is showing up like the elimination of general expectation errors and reduction of the risk of LOCA. On the other hand, due to the last news in 2006 AREVA charged 500 million euro for delay of Olkiluoto 3 reactor in Finland. Will it effect on the development of PSS?
- Are the passive safety systems useful to design fast breeder reactor, developed to environment-friendly close the fuel cycle?
- In our opinion what is the better solution between little modular plants like IRIS and bigger one like AP1000?
- Have all current plants some kind of passive safety systems?
- Is it possible to apply passive safety systems retroactively? Is it economically disadvantageous?
- Is it advantageous to invest money in research of this kind of security?
- Are passive safety systems really so beneficial in comparison with active ones?
- Can a nuclear reactor be a part of sustainable development? There still is radioactive waste for which we have no general solution.
- Should, if it is even possible, all current reactors be converted in the new types (AP1000, IRIS)?

ICARO round tables: Instructions for authors

First Author, Second Author, …, Coordinator (local professor)
Institute, Department, Town, Country

Abstract
Your manuscript must be in English. After the title (bold, 13 pt Times New Roman, and centred) and the authors (normal case, 10 pt Times New Roman, and centred) and their affiliation, it can start with a short abstract of maximum 3 to 5 lines describing the key elements of your contribution. This paragraph should be typeset in normal case, 10 pt Times New Roman, and the lines are justified in block mode.

Text

Your manuscript should then continue on the same page in 11 pt Times New Roman, single line spacing with a spacing of 0 pt before and after the paragraph mark, and the lines are justified in block mode. You should use DIN A4-size paper format. Top and right margins are 2,0 cm, bottom margin is 2,5 cm and left margin 3.5 cm.

Electronic form of contribution

Your paper of maximum 2 pages (references, tables and figures eventually extra) should be send in electronic form as a MS Word.doc file before 01/02/09. Please keep head and foot text as in this file (pagination and file name will be introduced automatically). Tables and figures should be inserted into the text at the appropriate place, and centred. They should be clearly identified with a caption, as shown below. The IP will be available on the website after the conference.

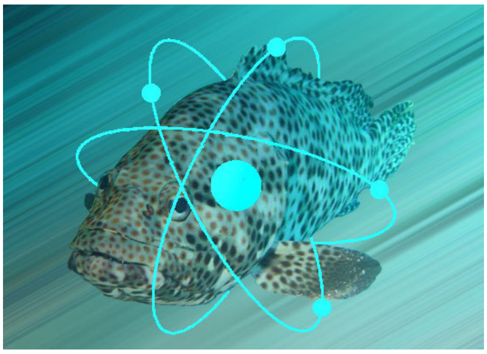

Fig 1. Caption for figure one

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bbb	789	012

Table 1. Caption for table one

Foot text

Use the standard foot text as in this file. File name will be automatically introduced if you use this .file as a reference format.

References and email

Please number your references and cite them in brackets [1]. The list of references should be at the end of your manuscript under the section heading 'References' in 10 pt Times New Roman. At the end of your manuscript you give the email address of all the authors.

References

[1] J. Smith, Proceedings of the 2nd International Conference on Radiation Protection Training: Future Strategies, Madrid, Spain, 17-19 September 2003, p. 99

[2] Nuclear Energy in a Sustainable Development Perspective, OECD, 2000 http://www.nea.fr/html/ndd/docs/2000/nddsustdev.pdf

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Deadline

Your contribution must arrive before 01/02/09. Please send them electronically to herwig.janssens@xios.be.

Your ppt-file for your presentation should be send in before 15/02/09.

Hint

Use this file from the beginning as a reference format for your contribution. Layout and standard foot text will be automatically introduced.