AGENCE DE L'OCDE POUR L'ÉNERGIE NUCLÉAIRE
OECD NUCLEAR ENERGY AGENCY

# Nuclear energy for today and tomorrow

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Mr. Chairman, ladies and gentlemen, dear colleagues,

It is an honour and a great pleasure for me to present during this opening session of ICONE13 the views of my organisation, the Nuclear Energy Agency of OECD (NEA). It is especially important for me to participate in this event hosted by The People Republic of China in a period of renewed interest worldwide for the nuclear option. The NEA is a governmental organisation working for its 28 member countries in the field of peaceful application of nuclear energy. The interest of our member countries for interaction with non-member countries – and in particular for cooperation with China – is not new and in the field of nuclear energy it is strengthened by the dynamisms of the Chinese nuclear programme.

While the NEA activities and interests cover a broad range of domains including most of the topics that will be addressed during this conference, I would like to focus my presentation today, after a rapid review of the status and trends of nuclear energy, on two key issues: economics and resources. In my concluding remarks, I will touch also upon research and development in an international context aiming at the design and implementation of the innovative nuclear energy systems needed for the 21$^{st}$ century.

## Status and trends of nuclear energy

At the beginning of 2005, a total of some 440 commercial nuclear reactors were in operation in 30 countries, representing about 366 GWe, and 27 reactors were under construction, representing about 19 GWe. During 2003 and 2004, 7 reactors were connected to the grid adding more than 6 GWe to the world nuclear capacity while 11 reactors were permanently shutdown, representing about 2.5 GWe. Nuclear energy produces some 16% of the world's electricity and in more than 10 countries it provides over one third. In OECD countries, the share of nuclear energy in electricity supply reaches nearly 25%.

There are great differences in nuclear energy policies of OECD countries and worldwide. For example, in the Far East, Japan and the Republic of Korea are continuing to increase their use of nuclear energy and China is implementing an ambitious diversified nuclear energy programme. In North America, there are indications that construction of new capacity may be announced in the United States before the end of the decade with government-funded programmes in place to help bring this about and the interest of Canada in relying on nuclear energy remains high. In OECD Europe, the situation is more contrasted. Finland and France have recently acted to expand their use of nuclear energy. On the other hand, several countries, such as Belgium, Germany, the Netherlands and Sweden, have policies to phase out nuclear energy albeit under some conditions.

Here, in China, one of the most ambitious nuclear energy programmes in history is underway in response to social and industrial development leading to rapidly growing energy demand as well as increasing concerns about local, regional and global environmental pollution. This programme should make China one of the top three users of nuclear energy in the world with one of the world's most advanced reactor fleets. China has also announced a nuclear desalination project as well as plans to construct a high-temperature, pebble-bed gas-cooled reactor. The Chinese nuclear energy programme is important not only for the country itself but for the international community as an example of a dynamic initiative also providing opportunities for other countries to cooperate in the development of nuclear systems for the 21$^{st}$ century.

Worldwide, only few new nuclear units have been ordered in recent years and the number of orders has been especially low in OECD Europe and North America. However, good technical performance and economic competitiveness of existing plants are strong incentives to keep them running. Therefore, many plant owners and operators are including in their plant life management programmes capacity up-rates and lifetime extensions. In many countries, lifetime management policies have permitted to increase significantly the nuclear capacity connected to the grids without building new plants.

Beyond, life extension, when policy makers consider ordering new nuclear power plants, a number of factors are taken into consideration that may affect decisions in one way or the other, including:

- projected growth of base load electricity demand;
- competitiveness and financial risks of new nuclear power plants as compared with alternatives, particularly on deregulated electricity markets;
- governmental concerns about security of energy supply;
- environmental considerations, in particular a greater recognition of the role that nuclear energy can play in reducing air pollution and greenhouse gas emissions; and
- social aspects related to public perception of risks associated with nuclear energy such as severe accidents, nuclear weapon proliferation or physical protection of facilities, and concerns about high level waste disposal.

In the light of current assessments of those factors, significant changes may be expected in nuclear energy trends during the 21$^{st}$ century. Some countries are beginning to consider that the balance of these factors supports construction of new nuclear power plants. This was highlighted, for example, by the statements made by many ministers and senior government officials at the recent *International Conference on Nuclear Power for the 21$^{st}$ Century*, organised by the International Atomic Energy Agency (IAEA) in cooperation with the OECD and the NEA, and hosted by the French Government in Paris, France, on 21-22 March 2005. Top level official representatives from 74 States including the People Republic of China and 10 international organisations participated in the conference. The final communiqué states that "…[a] vast majority of participants affirmed that nuclear power can make a major contribution to meeting energy needs and sustaining the world's development in the 21$^{st}$ century, for a large number of both developed and developing countries…"[1].

The renewed interest of decision makers for nuclear energy, visible worldwide, is motivated by an increasing demand for clean, secure and competitive energy. World demand for electricity is expected to double from 2002 through 2030 to meet the needs of increasing population and sustained economic growth. The projections developed by the International Energy Agency (IEA), the organisation of the OECD family in charge of energy issues, indicate that about 4 800 GWe of new capacity will be needed by 2030 to meet the projected increase in electricity demand and to replace ageing infrastructure. Growth is expected to be strongest in developing countries seeking to improve their standards of living and their industrial production infrastructures.

Even if only a fraction of this new capacity would rely on nuclear reactors, the total demand is so large that a significant growth in orders for new nuclear power plants is to be expected. One of the challenges of this century for the nuclear industry and the R&D organisations that support it, as well as for regulators and governments, will be to adapt its capabilities to increasing growth after a period of relative stagnation that lasted more than one decade.

In addition to electricity generation, nuclear reactors offer a potential means of producing desalinated water or hydrogen. Nuclear energy could make hydrogen available without the greenhouse gas emissions that are characteristic of its current methods of production. Any electricity-producing reactor can produce hydrogen through the process of electrolysis. The overall efficiency of production of hydrogen in this way, however, is relatively low. High-temperature reactors hold the promise to generate hydrogen at much higher efficiencies using thermo-chemical processes.

If these processes can be successfully developed and are deployed to meet growing hydrogen demand, the potential exists for significantly increased nuclear capacity above that required for electricity generation. For example, to replace motor vehicle fuel with hydrogen in the United States would require on the order of 165 million tonnes of hydrogen each year[2]. Over 560 dedicated high-temperature gas reactors would be needed to produce this quantity of hydrogen.

## Economics of nuclear energy

I would like to turn now to economics, a key issues and a topic thoroughly anlysed within OECD. Economic competitiveness always has been a cornerstone in decision making for electricity generation options but in open and competitive energy markets economic attractiveness is often "the" driving factor. In this regard, it should be noted that the volatility of fossil fuel prices, notably natural gas for electricity generation, along with moves to internalise the costs of carbon emissions, have a dramatically influence on the relative competitiveness of nuclear energy as compared with alternatives.

The two OCDE agencies dealing with energy – IEA and NEA – have just released a study entitled *Projected Costs of Generating Electricity: 2005 Update* that

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1 Final Statement, International Ministerial Conference: "Nuclear Power for the 21$^{st}$ Century", Paris, France, 22 March 2005.

2 2001 consumption of motor vehicle fuel in the United States was 163,478 million gallons according to the United States Bureau of Transportation Statistics. One kilogram of hydrogen has energy equivalent to one gallon of gasoline.

illustrates the economics of different electricity generating technologies. Cost data used in the study was provided for more than 130 power plants, including 27 coal-fired power plants, 23 gas-fired plants, 13 nuclear plants, 35 power plants using intermittent renewable energy sources, 24 combined heat and power (CHP) plants using various fuels and 10 plants based on other fuels or technologies. The technologies and plant types covered by the study include units under construction or planned that could be commissioned in the 18 respondent countries between 2010 and 2015, and for which they have developed cost estimates generally through paper studies or bids.

The nuclear power plants considered in the study have specific overnight investment costs varying between 1000 and 2000 USD/kWe in most cases. Their construction times, which determine the added investment costs needed to finance interests during construction, range from 5 years in three countries to 10 years in one country. In nearly all countries 90% or more of the upfront capital expenses are incurred within 5 years or less.

At a 5% discount rate, the levelised costs of nuclear electricity generation range between 21 and 31 USD/MWh except in two cases. Investment costs represent the largest share of total levelised costs, around 50% on average, while O&M costs represent around 30% and fuel cycle costs around 20%. At a 10% discount rate, the levelised costs of nuclear electricity generation range between 30 and 50 USD/MWh except in two cases. The share of investment in total levelised generation cost is around 70% while the other cost elements, O&M and fuel cycle, represent in average 20% and 10% respectively. It is important to stress that the levelised costs calculated in the study include all the costs associated with decommissioning and waste management and disposal.

In their conclusions, the experts who carried out the study stress that, according to the data provided, there is no universal winner in terms of technology or fuel source for electricity generation. However, as far as nuclear power is concerned, the results of the study show that it is in most cases the least cost option for base load electricity supply in countries which consider its use.

Indeed, at 5% discount rate, nuclear power is economically attractive in nearly all countries where it is considered. At 10% discount rate the picture is less clear, the most economically attractive option depending on local and national context, but nuclear electricity remains the cheapest in many cases. It should be noted that the internalisation of external costs associated with carbon emissions, which will occur progressively in Annex I countries of the Kyoto Protocol, will enhance the competitive margin of nuclear energy.

Furthermore, regarding generation cost stability in time, it should be noted that the share of nuclear fuel cycle cost in the total levelised cost remains rather low in spite of the a dramatic increase in uranium price over the past several years, almost 200% between 2001 and 2004, with no indication yet on whether the upswing has ended. On the other hand, a similar doubling in the price of natural gas that might occur anytime in the light of recent hydrocarbon price volatility would add 70 to 90% to the cost of electricity generated by gas-fired plants.

The contribution of nuclear energy to diversity and security of supply is also worth noting. Security of supply is an intrinsic characteristic of nuclear energy since nuclear fuel is easy and cheap to stock and uranium resources are widely distributed in the world. Significant resources exist in Australia, North America (e.g. Canada), South America (e.g. Brazil), Africa (e.g. Namibia and Niger), Eastern Europe (e.g. Russia) and Central Asia (e.g. Kazakhstan). This distribution provides security and diversity of supply.

## Nuclear fuel resources

Turning now to natural resources that are required to support nuclear energy development, I will try to address the concern often raised about the capability to provide enough fuel for nuclear power plants in the case of a dramatic revival of nuclear energy, a question that becomes even more acute when considering non-electricity applications such as water desalination and hydrogen production. The short answer to this question is "yes, nuclear fuel source is more than adequate" as illustrated by facts and figures drawn from several decades of statistical data collection and analysis within the Nuclear Energy Agency in cooperation with the IAEA.

As reported in *Uranium 2003: Resources, Production and Demand* (the Red Book), total known conventional resources are about 3.5 million tonnes U, recoverable at less than USD 80/kgU[3] and reach some 4.6 million tonnes U when considering all resources recoverable at less than USD 130/kgU. Including the undiscovered conventional resources, the total is around 9.8 million tonnes U. Additionally since the geographical coverage of uranium exploration is not yet complete worldwide there remains the potential for discovery of new resources.

Beyond conventional resources, uranium resources classified as unconventional, in which uranium exists at very low grades or can only be recovered as a minor by-product, include about 22 million tonnes that occur in phosphate deposits. The technology to recover the uranium from phosphates is mature; it has been used in Belgium and in the United States for example. Although high recovery costs limit the attractiveness of these resources, they could become economically recoverable if price levels would reach some USD 60-100/kgU. The world's oceans have been estimated to contain up to 4 000 million tonnes of uranium but at present, only laboratory-scale quantities have been extracted and the cost of extraction is estimated to be very high, on the order of USD 300/kgU.

In relation to current demand rates, known conventional resources are sufficient for several decades. Exploitation of undiscovered conventional resources could increase this to several hundreds of years, though significant exploration and development efforts would be required to move these resources to technically and economically recoverable categories. Unconventional resources, e.g. phosphate deposits and seawater, could fuel nuclear energy for millennia. Estimated phosphate resources alone could supply demand for roughly 300 years at the 2004 rate of consumption.

Besides uranium, thorium, abundant and widely dispersed, could also be used as a nuclear fuel resource. Total thorium resources are estimated to more than 4.5 million tonnes but these estimates are considered conservative because data from many countries are not included and a historically weak market demand has limited thorium exploration. The nuclear energy systems using thorium have been studied in several countries but extensive R&D programmes would be needed to demonstrate their technical viability and economic competitiveness on an industrial and commercial scale.

More importantly, the longevity of uranium and thorium resources may be increase dramatically through technology progress. Evolutionary and innovative reactor and fuel cycle technologies could radically increase the efficiency with which these resources are used. Advanced systems also may address economic,

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[3] USD 1/kgU = USD 0.38/lb$U_3O_8$.

safety, security, non-proliferation and waste concerns. Fast neutron reactors can be operated in a breeding mode and produce more fuel than they consume through reprocessing spent fuel and recycling fissile materials. For example, if a full recycling fuel cycle would be used in high-temperature gas fast reactors, the quantity of uranium needed to produce electricity, hydrogen or water would be about 100 times less than with once through water reactors.

**Concluding remarks**

Nuclear energy is now at a turning point. It has demonstrated its economic competitiveness in many countries and the natural resources are there to support its broader development. Technological progress will be a major factor in defining the long-term future of nuclear energy and the amount of natural resources needed to fuel nuclear systems. The R&D efforts required to support this technology progress are a challenge that joint international undertakings may help to address.

Several major international programmes are devoted to the development of advanced nuclear technologies, for example, the Generation IV International Forum (GIF) and the IAEA International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO). Ongoing activities within GIF focus on six promising concepts: Gas-Cooled Fast Reactor System, Lead-Cooled Fast Reactor System, Molten Salt Reactor System, Sodium-cooled Fast Reactor System, Supercritical-Water-Cooled Reactor System and Very High Temperature Reactor System. The R&D framework and the programmes necessary to demonstrate the viability of those systems have been outlined already. The GIF participants have asked the Nuclear Energy Agency to provide the Technical Secretariat of the project. Undoubtedly the outcomes from such R&D programmes will facilitate the development of nuclear systems contributing to global energy supply for the 21$^{st}$ century.

This Conference will address in detail the topics that I have just briefly outlined and address much more issues relevant for the future of the nuclear option. The engineering focus of ICONE Conferences offers unique opportunities exchanging information on scientific research and technology development in the field of nuclear energy. Such meetings are a key contribution to enhanced international cooperation in the domain of peaceful applications of nuclear energy. The OECD Nuclear Energy Agency is highly interested in the findings and recommendations from such exchanges to focus its future activities on addressing the needs of member and non-member countries. I wish you very fruitful discussions and thank you for you attention.