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The OECD Nuclear Energy Agency (NEA) is an intergovernmental organisation established in 1958. Its primary objective is to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes. It is a non-partisan, unbiased source of information, data and analyses, drawing on one of the best international networks of technical experts. The NEA has 28 member countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, Norway, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission takes part in the work of the NEA. A co-operation agreement is in force with the International Atomic Energy Agency.

For more information about the NEA, see:
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Cover page photo credits: Tobernite (CEA, France), centrifuges at a uranium enrichment plant (URENCO), Shika-1 (Hokuriku Electric Power Company, Japan), power lines (F. Vuillaume, OECD/NEA). Page 3 photo credit of Luis Echávarri (M. Lemelle, France).

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Nuclear energy: strengthening its position

Today's, and tomorrow's, energy sources need to be safe, clean and affordable. Nuclear energy continues to strengthen its position in this regard and is increasingly being seen and accepted as forming a part of the energy mix. This was reflected in the widespread, high-level participation in the international conference on Access to Civil Nuclear Energy held at the OECD Conference Centre in March. More recently, nuclear energy was recognised as a low-carbon technology aimed at controlling greenhouse gas emissions, and at the same time ensuring secure energy supply at reasonable costs, when I was honoured with the 2010 EURELECTRIC award. The *Nuclear Energy Technology Roadmap,* a joint publication just released by the International Energy Agency (IEA) and the OECD Nuclear Energy Agency (NEA), estimates that almost one quarter of global electricity could be generated from nuclear power by 2050, making a major contribution to cutting greenhouse gas emissions.

Another recent, joint IEA/NEA publication presents the latest cost data available for a wide variety of fuels and technologies, including coal and gas (with and without carbon capture), nuclear, hydro, onshore and offshore wind, biomass, solar, wave and tidal as well as combined heat and power. It provides levelised costs of electricity for almost 200 plants in 21 countries and contains an extensive sensitivity analysis of the impact of variations in key parameters such as discount rates, fuel prices and carbon costs. The article on page 4 discusses the report's main findings as well as other issues surrounding the economic competitiveness of nuclear power.

Nuclear energy is also particularly well-placed for ensuring security of energy supply. Currently identified uranium resources are already sufficient for over 100 years of supply (at 2008 levels of consumption) and are available in geographically diversified, politically stable regions. Some of the latest figures on uranium resources, production and demand are provided in the article on page 9. It should also be noted that thanks to one of the most strictly regulated and closely monitored sets of safety standards, the nuclear energy safety record continues to be strengthened, currently benefiting from about 13 000 reactor-years of experience worldwide. As the article on page 18 shows, safety remains a priority for the nuclear sector and further research efforts are being pursued. Readers will also discover in the pages that follow a number of other articles on issues of interest being addressed by the Agency.

In closing, I would like to take this opportunity to congratulate those who have contributed towards the establishment and development of the International School of Nuclear Law, a joint endeavour between the NEA and the University of Montpellier 1 in France, which is celebrating its 10th anniversary this year. A short description of the programme is provided on page 22. These and other efforts are each playing a part in helping to make nuclear energy safe, economic and environmentally acceptable.

Luis E. Echávarri
NEA Director-General

How competitive is nuclear energy?

by J.H. Keppler*

The economic competitiveness of nuclear energy will be crucial for determining its future share in world electricity production. In addition, the widespread liberalisation of power markets, in particular in OECD countries, reinforces the role of commercial criteria in technology selection.

The recently published IEA/NEA study on *Projected Costs of Generating Electricity: 2010 Edition* (IEA/NEA, 2010) provides important indications regarding the relative competitiveness of nuclear energy in OECD member countries as well as in four non-OECD countries (Brazil, China, Russia and South Africa). According to its Executive Summary:

> *First, in the low discount rate case [5%], more capital-intensive, low-carbon technologies such as nuclear energy are the most competitive solution compared with coal-fired plants without carbon capture and natural gas-fired combined cycle plants for baseload generation… Second, in the high discount rate case [10%], coal without carbon capture equipment, followed by coal with carbon capture equipment, and gas-fired combined cycle turbines (CCGTs), are the cheapest sources of electricity… The results highlight the paramount importance of discount rates and, to a lesser extent, carbon and fuel prices when comparing different technologies.*

Going beyond this general finding, the study also shows that the relative competitiveness of nuclear energy varies widely from one major region to another, and even from country to country. A breakdown by regions, for instance, shows that nuclear energy remains the most competitive option for baseload generation, including at a 10% discount (interest) rate, in OECD Asia and OECD North America (see graphs next page). The statement quoted above thus reflects the overall average for the study's sample of nuclear plants, but not necessarily each national or regional situation. In fact, the large amount of data provided by European countries, where nuclear has comparatively higher costs, has had a skewing effect on the results.

While the study provides a useful snapshot of the costs of generating electricity with different technologies, it does not provide an absolute picture of the competitiveness of nuclear energy. Like any study, *Projected Costs of Generating Electricity* makes a number of common assumptions about discount rates as well as carbon and fuel prices. In addition, its calculations are based on a methodology that is referred to as the levelised cost of electricity (LCOE), which assumes that all risks are included in the interest or discount rate, which determines the cost of capital. In other words, neither the electricity price risk for nuclear and renewables, nor the carbon and fuel price risk for fossil fuels such as coal and gas, receive specific consideration. The decisions of private investors, however, will depend to a large extent on their individual appreciations of these risks.

The competitiveness of nuclear energy thus depends on three different factors which may vary greatly from market to market: interest rates, carbon and fuel prices, and the volatility of electricity prices. These factors are discussed below.

Interest rates and the cost of capital

The generic (not technology-specific) risk of doing business in a country is expressed in the discount or interest rate and determines the cost of capital. This affects capital-intensive technologies such as nuclear and renewables comparatively more than less capital-intensive technologies such as gas. Based on interest rates of 5% to 10%, the fixed investment costs vary between 11% and 17% of total lifetime costs for gas-fired power plants, between 26% and 40% for coal-fired plants, between 59% and 76% for nuclear power plants, and between 78% and 85% for wind parks (IEA/NEA, 2010). The range is wider for nuclear power and coal plants since their construction periods are longer. This means that at higher interest rates, costly interest during construction accrues more significantly than for other technologies.

Reducing construction periods or lead times is indeed an important parameter in determining the cost competitiveness of nuclear energy. Reducing lead times from seven years to four would reduce total capital costs for a typical plant by 13% at a 10% annual interest rate and by 7% at a 5% annual interest rate.[1]

The question is often posed whether an interest rate of 5% is not unrealistically low for a private company, considering that the interest rate corresponds to the rate of expected profit for the investors who make their capital available. This is indeed of utmost importance. If 5% is a realistic interest rate, nuclear energy is easily the most competitive source for

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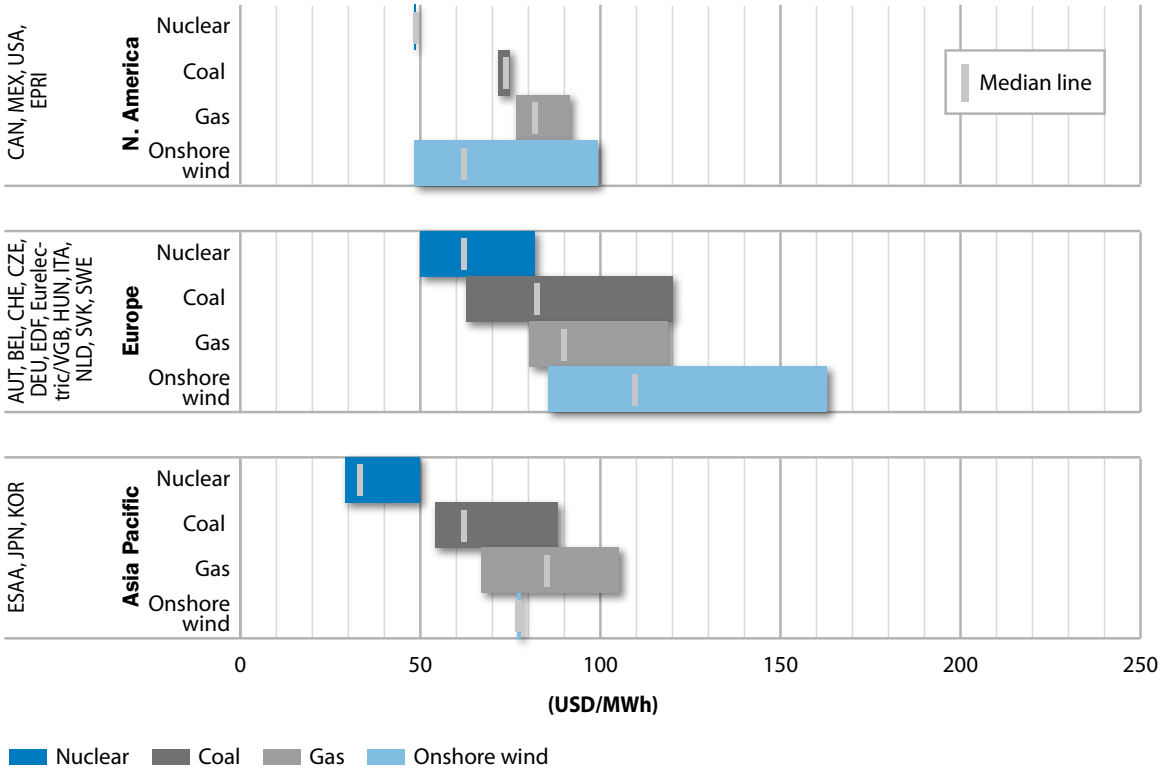
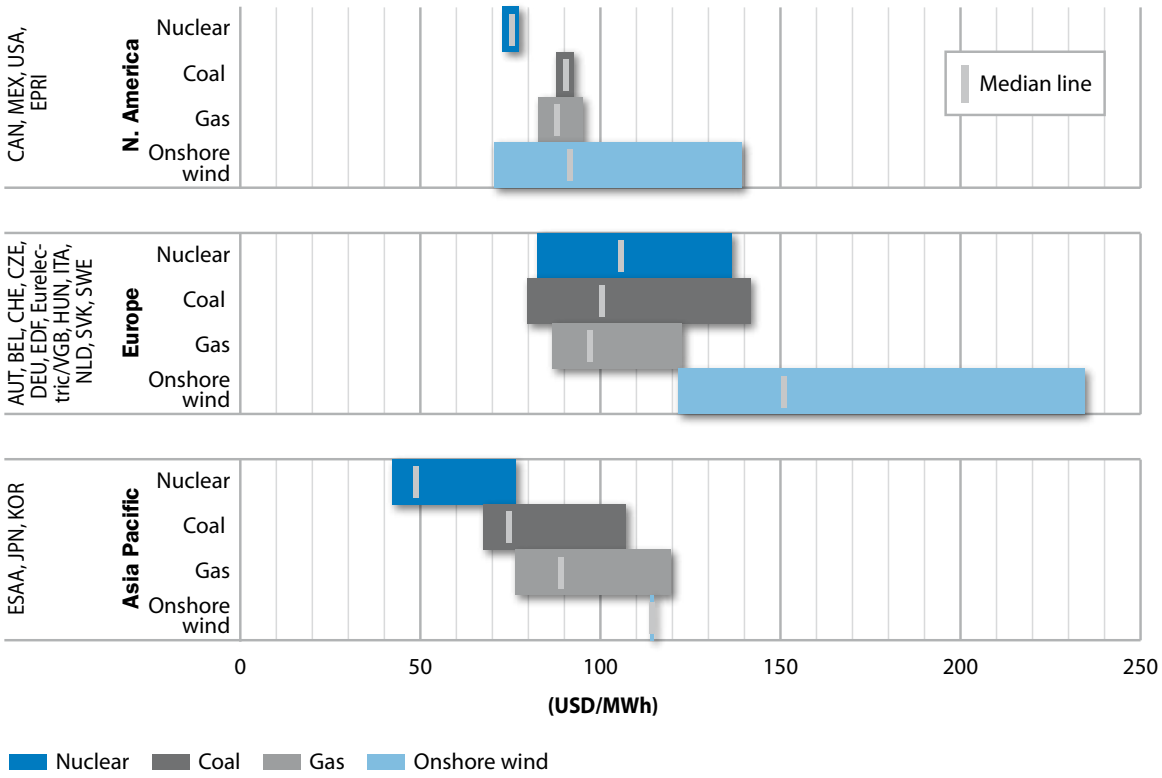
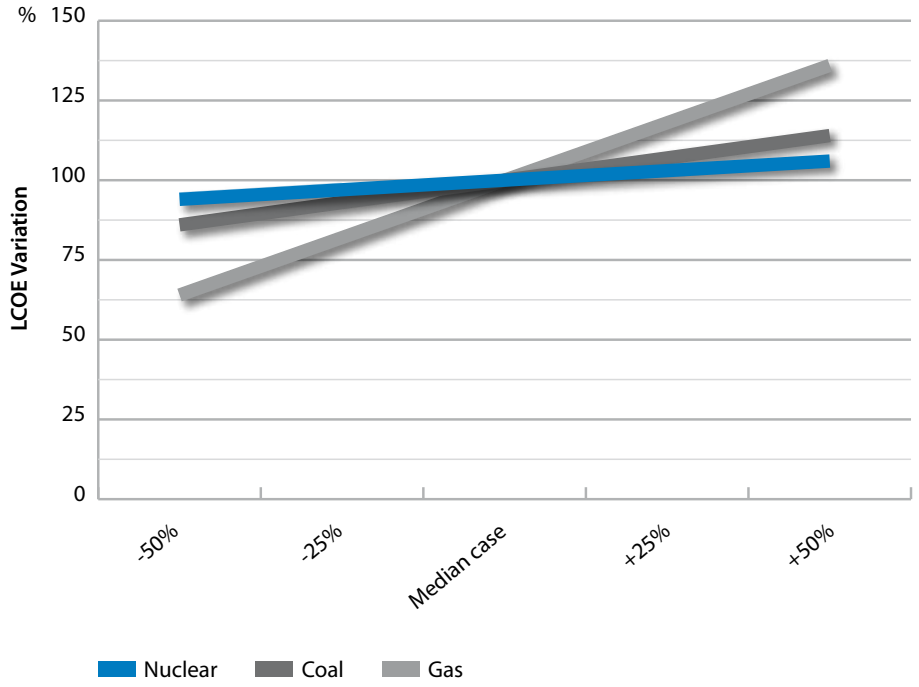
Regional ranges of LCOE for nuclear, coal, gas and onshore wind power plants
(at 5% discount rate)



Regional ranges of LCOE for nuclear, coal, gas and onshore wind power plants
(at 10% discount rate)



Changes in the LCOE of different technologies in response to changes in the fuel price



Source: Adapted from IEA/NEA (2010).

baseload (around-the-clock) electricity generation. If real rates are closer to 10%, the case is much more difficult to make.

The first answer to this question is that the calculations used here and in the study are based on *real* interest rates that are net of inflation. However, when a bank provides a quote or an investor specifies a hurdle rate for his return on capital, in the real world they quote nominal rates. This means that 5% real interest needs to be compared to 7% nominal interest, which includes 2% inflation (a widespread and not unrealistic assumption). In terms of the cost of a commercial loan, a 7% interest rate is by no means low. In December 2009, the average nominal yield (interest rate) on US investment-grade corporate bonds (rated BBB or higher) was 4.6%. The average nominal yield on high-yield ("junk") bonds was 9.8%. Factoring out inflation, at the end of 2009 real yields for US corporate bond varied between 2.6% for investment-grade bonds and 7.8% for high-yield bonds. Given that very few energy utilities are in the "junk-bond" category, a 5% real interest rate seems to be a very realistic and even generous assumption for the price of debt capital.

The true problem is a slightly different one. In a liberalised electricity market no company would be able to finance all of its investments with the help of relatively risk-averse debt investors.[2] A substantial part of the investment would have to be carried by equity investors with a direct stake in the project, who would be willing to incur higher risks such as market and price risk. Higher risk, however, means higher average returns, which means that equity investors may demand nominal rates between 10% and 15% depending on the project. The cost of debt and the cost of equity weighted according to their respective share in financing together form what is called the weighted average cost of capital (WACC). For example, if the cost of debt is 5% nominal, the cost of equity is 15% nominal and their respective shares are half and half, then the nominal WACC would be 10% and the real cost of capital net of inflation would be 8%. An IEA analysis on the total cost of financing for US electricity companies showed that the WACC was 10.5% in the fourth quarter of 2008 (IEA, 2009). The real rate was thus 8.5%. Considering that the end of 2008 saw the height of the financial crisis, this is probably on the high side. We may conclude that the real total cost of capital for electricity companies is probably in the range of 7% to 9% real or 9% to 11% nominal. Using two cases of 5% and 10% real thus provides a very realistic range.

Carbon and fuel prices

The second decisive factor determining the competitiveness of nuclear energy is the price of carbon or CO_2 emissions. The 2010 edition of the *Projected Costs of Generating Electricity* assumed for the first time a price of USD 30 per tonne of CO_2 that would prevail over the complete lifetime of all generation projects. USD 30 is higher than the current price of roughly EUR 16 (USD 21) in the European Emission Trading

Scheme (EU ETS). However, it is much lower than what most modellers indicate to be the explicit or implicit price that would need to prevail to stabilise global emissions at a level that would limit the increase of global mean temperatures to 2° Celsius by 2050.[3] While estimates of the prices necessary to achieve such stabilisation vary widely, there is no doubt that they will need to be significantly above USD 100 per tonne of CO_2 and probably above USD 200 per tonne of CO_2. There is thus a realistic expectation that carbon prices might rise, perhaps significantly in the coming decades.

The competitive advantage of nuclear power in this context is, of course, that it produces largely carbon-free, baseload electricity at stable variable costs and is unaffected by any changes in the global climate regime. The fuel with which nuclear energy is in direct competition is coal, which emits 0.8 tonne of CO_2 per MWh for a typical coal plant (IEA/NEA, 2010). A simple doubling of the carbon price would increase its total cost by between 30% and 37%, while for a gas-fired combined cycle turbine with emissions of 0.35 tonne of CO_2 per MWh, cost would go up between 11% and 12%. Clearly, carbon prices are a decisive factor for determining the competitiveness of nuclear energy. It is thus no surprise that potential investors in new nuclear power plants in the United Kingdom, for example, are pressing the UK government for a carbon levy of around EUR 30 (USD 40) per tonne of CO_2 (Johnson, 2010). This would, of course, make the competitiveness of nuclear energy very robust indeed.

According to the IEA/NEA study, a similar reasoning holds for fuel prices. Even a doubling of the price of uranium would only increase the total cost of electricity produced by a nuclear power plant by 10%. However, doubling the fuel price would increase the total cost of gas-fired electricity by 70% or USD 61 per MWh! For coal, the total cost would increase by about 25% or USD 18. The stability of variable costs is thus a distinct competitive advantage of nuclear energy. In all fairness, there is also some likelihood that gas prices might go down in the next few years due to overinvestment in the expectation of ever-rising gas prices. However, energy choices are long-term choices. A decision to construct a nuclear power plant today can commit a company up to a century if one includes construction, decommissioning and dismantling. There is a very real probability that gas and coal prices will rise over this period. For a large, diversified utility in the business for the long run, it is thus almost indispensable to have a significant share of nuclear energy in its portfolio in order to hedge itself against a rise in coal, gas and carbon prices over the next 10, 30 or even 50 years.

Volatility of power prices and types of electricity markets

The third key aspect impacting the competitiveness of nuclear energy is the most technical one as it is related to the exposure of different technologies to the volatility of electricity prices. Its impact thus varies greatly with the form of market organisation, in particular whether prices are liberalised or regulated.

In liberalised markets, although gas prices can be very volatile, investors in gas-fired power plants are to some extent protected against price swings given that gas-fired power generation is the fuel with the highest variable cost and thus frequently sets the electricity price. In other words, if gas prices go up or down, so will electricity prices and the stream of net profits for the investor, the investor's only true risk, stays the same. Investors in nuclear energy instead would be exposed to more volatility in profits precisely because their costs remain stable while their revenues vary.

There is thus a mismatch between private and social incentives. From a social point of view, stable variable costs and stable electricity prices as provided by nuclear energy would, of course, be an advantage for investment, industrial consumers and households. Due to the peculiar price setting mechanism in the electricity market, however, only one technology (gas) profits from an automatic hedge through the alignment of its variable cost and electricity prices. Nuclear, despite its contribution to long-term cost price stability in electricity markets, does not benefit from such an automatic hedge. Coal is somewhere in the middle, as coal and gas prices frequently vary in tandem.

Electricity price volatility also affects the expected profits of gas and nuclear through another channel. Depending on whether interest rates are estimated at 5% or 10%, the fixed investment costs of gas-fired power plants vary between 11% and 17% of total lifetime costs, and between 59% and 76% for nuclear power plants (IEA/NEA, 2010). This means that investors are facing different effective risks if electricity prices fall, temporarily or permanently, below average costs. As soon as prices fall below the variable costs of gas-fired production, gas-fired production will stop, but production of nuclear energy will continue. What looks at first sight like a comparative disadvantage of gas-fired production is in fact a comparative strength in adversity. The investor in gas-fired capacity will exit the industry at a relatively small cost (the capital cost). The investor in nuclear capacity will lose proportionately more as there will be little chance to recover the massive capital cost, even though small profits will continue to be made over the lifetime of the plant.

In order to ensure its competitiveness and attractiveness for investors, nuclear energy thus requires stable long-term pricing arrangements. This can be achieved in either of two manners. First, it can be achieved through straightforward price regulation which establishes a given tariff. It is, of course, no coincidence that of the 21 projects for new nuclear plants in the United States, 19 are being undertaken in regulated markets.[4] The alternative for liberalised

markets would be long-term supply contracts. Long-term hedging provisions locking in stable electricity prices are indeed an alternative that is actively being explored.[5] However, larger-scale adoption might suffer from limited liquidity in markets for multi-year forward contracts and would thus carry additional financing costs.

Conclusion

The real competitiveness of nuclear energy cannot be determined once and for all in the abstract. It is clear that in an environment with low financing costs, high carbon prices and stable electricity prices, the competitiveness of nuclear energy is manifest. On the other hand, in an environment with high financing costs, low or absent carbon prices and volatile electricity prices, the economic case for nuclear energy is harder to sustain. Both observations also apply to renewable energies, which just as nuclear energy are high fixed cost, low-carbon technologies.

Following the above observations, in order to bolster the long-term competitiveness of nuclear energy, the nuclear industry and governments would need to:

1. develop financing mechanisms with the help of long-term investors that keep financing costs at a minimum;
2. help establish, perhaps in co-operation with the renewable energy industry, a stable, long-term carbon price;
3. help create, again possibly in co-operation with the renewable energy industry, market conditions that minimise electricity price volatility.

So far the industry and governments have just begun to address the first point. The sector's long-term competitiveness will, however, also depend on progress made in addressing the second and third.

Notes

1. This calculation only takes into account the cost-of-capital effect with constant overnight costs. Normally one would expect additional savings from a reduction in lead times. The most obvious item would be labour costs, which would need to be paid over a much shorter period.
2. Indeed, the considerations which follow apply only to fully liberalised energy markets. In markets where governments are major shareholders of energy companies, financing costs might be much lower. Even 100% debt finance might be a possibility in such cases.
3. According to the influential Stern Review on *The Economics of Climate Change,* such a limited increase would correspond to a reduction of global annual emissions by 50% and a reduction in the emissions of OECD countries of roughly 80%. Unsurprisingly, it foresees a near-doubling of global nuclear capacity by 2050 to 700 GWe as one of the measures to stabilise greenhouse gas concentrations.
4. See www.nrc.gov/reactors/new-reactors/new-licensing-files/expected-new-rx-applications.pdf.
5. See the Exeltium project in France at http://medias.edf.com/fichiers/fckeditor/Commun/Presse/Communiques/EDF/2010/cp_20100325.pdf.

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The latest figures on uranium

by R. Vance*

According to the latest figures on uranium, soon to be published by the NEA, uranium resources, production and demand are all on the rise. Exploration efforts have increased recently in line with the expected expansion of nuclear energy in the coming years. Total identified resources have grown and are now sufficient to cover 100 years of supply at 2008 rates of consumption. Costs of production have, however, also increased.

This article is based on the latest edition of the "Red Book", *Uranium 2009: Resources, Production and Demand*, which presents the results of the most recent biennial review of world uranium market fundamentals and a statistical profile of the world uranium industry as of 1 January 2009. It contains official data provided by OECD Nuclear Energy Agency (NEA) and International Atomic Energy Agency (IAEA) member countries on uranium exploration, resources, production and reactor-related requirements. Projections of nuclear generating capacity and reactor-related uranium requirements through 2035 are also provided as well as a discussion of long-term uranium supply and demand issues.

Exploration

Worldwide exploration and mine development expenditures have more than doubled compared to figures reported in the 2007 edition of the Red Book, despite declining uranium market prices since mid-2007. Most major producing countries reported increasing expenditures, as efforts to identify new resources and to bring new production centers online moved forward. The majority of global exploration activities remain concentrated in areas with potential for hosting unconformity-related and ISL (*in situ* leach) amenable sandstone deposits, primarily in close proximity to known resources and existing production facilities. However, since uranium prices remain higher than those that prevailed during the last two decades of the 20th century, even with the price decline since mid-2007, "grass roots" exploration has been stimulated, as well as increased exploration in regions known to have good potential based on past work. Based on preliminary data, domestic exploration and development expenditures are expected to decline somewhat, but to have remained strong throughout 2009.

CEA

Kasolite crystals containing uranium.

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Cameco

The Port Hope uranium production centre in Canada.

Resources

Total identified resources as of 1 January 2009 increased by about 15% compared to 1 January 2007. A high-cost category of <USD 260/kgU was used in this edition in response to both the generally increased market prices for uranium since 2002 and increased mining costs. Although total identified resources have increased overall, there has been a significant reduction in lower-cost resources owing to increased mining costs. Though a portion of the overall increases relate to new discoveries, the majority result from re-evaluations of previously identified resources. At 2008 rates of consumption, identified resources are sufficient for over 100 years of supply.

Total undiscovered resources, estimated at 10.4 million tonnes of uranium (tU), declined slightly from the 10.5 million tU reported in the 2007 edition of the Red Book. It is important to note however that some countries, including major producers with large identified resource inventories, do not report resources in this category.

Resource figures are dynamic and related to commodity prices. The overall increase in identified resources from 2007 to 2009, equivalent to about 15 years of supply of 2008 uranium requirements, demonstrate that uranium prices continue to impact resource totals and that with market incentives, new resources are readily identified. The uranium resource figures presented in this volume are a "snapshot" of the situation as of 1 January 2009. Favourable market conditions will stimulate exploration and, as in the past, increased exploration efforts will lead to the identification of additional resources through intensified investigation of existing deposits and the discovery of new deposits of economic interest. For example, recent efforts in Australia have led to the discovery of new deposits and continued efforts in Canada have led to discoveries of high-grade deposits in the Athabasca Basin.

Production

Uranium production in 2008 (the most recent year with full production figures) totalled 43 880 tU, a 6% increase from the 41 244 tU produced in 2007 and an 11% increase from the 39 617 tU produced in 2006. As in 2006, a total of 20 countries reported output in 2008. Global production increases between 2006 (data from the 2007 edition of the Red Book) and 2008 were driven principally by significant increases in Kazakhstan (76%). More modest increases were recorded in Australia, Brazil, Namibia and the Russian Federation. Reduced production was recorded in a number of countries between 2006 and 2008 (including Canada, Niger and the United States) owing to a combination of lower ore grades and technical difficulties. *In situ* leach (ISL, sometimes referred to as *in situ* recovery, or ISR) production is rising rapidly in global importance, principally because of capacity increases in Kazakhstan. Global uranium production in 2009 is expected to grow by about 15% compared to 2008, with Kazakhstan continuing to ramp up production and production beginning in Malawi.

Environmental aspects of uranium production

Environmental aspects of the uranium production cycle can generally be divided into two areas. The first encompasses ongoing efforts to remediate the consequences of uranium mining practices, no longer licensed today, that resulted in a number of legacy uranium mining sites in several countries. Included in the 2009 edition of the Red Book are updates of some of these activities. These experiences are an important reminder of the consequences of outdated mining practices that must continue to be avoided in coming years as uranium mining is poised to expand to new producing countries.

The second area encompasses efforts to ensure that ongoing operations are conducted in a fashion that protects people and the environment and avoids the creation of new uranium mining legacies. Information presented in a number of national reports include accounts of crucial aspects of modern uranium mine development, such as environmental assessment processes prior to mine openings or expansions, monitoring programmes at mines currently in production, efforts to reduce water consumption and the establishment of new, more stringent environmental radiological protection regimes. Uranium mining can bring benefits to local populations and the use of funds raised through resource taxes on uranium mining operations, as well as efforts by the mining companies themselves, to improve living conditions of people in the vicinity of mining operations are outlined. Uranium mining companies also continue to obtain the internationally recognised ISO 14001 for sustainable management and environmental protection.

Uranium demand

At the end of 2008, a total of 438 commercial nuclear reactors were connected to the grid with a net generating capacity of about 373 GWe. Uranium acquisitions have declined in recent years as generally higher uranium prices have motivated utilities to specify lower tails assays at enrichment facilities in order to reduce uranium consumption. By the year 2035, world nuclear capacity is projected to grow to between 500 and 785 GWe net. Accordingly, world reactor-related uranium requirements are also projected to rise.

Significant regional variation exists within these projections. Nuclear energy capacity and resultant uranium requirements are expected to grow significantly in the East Asia region and in non-European Union countries in Europe and western Asia. Nuclear capacity and requirements display a wide variation in North America and in the European Union. However, there are uncertainties in these projections as there is ongoing debate on the role that nuclear energy will play in meeting future energy requirements.

Supply and demand relationship

At the end of 2008, world uranium production provided over two-thirds of world reactor requirements, with the remainder being met by supplies of uranium already mined (so-called secondary sources), including excess government and commercial inventories, the delivery of low enriched uranium (LEU) arising from the down-blending of highly enriched uranium (HEU) derived from the dismantling of nuclear warheads, re-enrichment of depleted uranium tails and spent fuel reprocessing.

Uranium mine development has responded to the market signal of increased prices and rising demand. As currently projected, uranium mine production could satisfy projected high-case world uranium requirements until the late 2020s. Should demand increase as projected growth in nuclear power is realised, uranium prices would strengthen allowing mine production capacity to be increased even further. However, sufficiently high market prices will be required to fund such mine development activities, especially in light of rising costs of production. Secondary sources will continue to be required, complemented to the extent possible by uranium savings achieved by specifying lower tails assays at enrichment facilities and possible technical developments in fuel cycle technology.

Although information on secondary sources is incomplete, they are generally expected to decline in importance through the next decade. However, there remains a potentially significant amount of previously mined material (including for military requirements), and the possibility that at least some of this material could make its way to the market in a controlled fashion cannot be discounted. Nonetheless, a sustained strong market for uranium will be needed to stimulate the timely development of production capability and to increase the identified resource base should growth in nuclear generating capacity follow currently projected trends. However, because of the long lead times required to identify new resources and to bring them into production (typically on the order of ten years or more), the relatively sparse global network of uranium mine facilities and geopolitical uncertainties in some important producing countries, uranium supply shortfalls could potentially develop.

Conclusions

Despite recent declines stemming from the global financial crisis, world demand for electricity is expected to continue to grow significantly over the next several decades to meet the needs of an increasing population and economic growth. The recognition by an increasing number of governments that nuclear power can produce competitively priced, baseload electricity that is essentially free of greenhouse gas emissions, coupled with the role that nuclear can play in enhancing security of energy supply, increases the prospects for growth in nuclear generating capacity, although the magnitude of that growth remains to be determined.

Regardless of the role that nuclear energy ultimately plays in meeting rising electricity demand, the uranium resource base is more than adequate to meet projected requirements. Meeting even high-case requirements to 2035 would consume less than half of the identified resources described in this edition. Nonetheless, the challenge remains to develop mines in a timely and environmentally sustainable fashion as uranium demand increases. A strong market will be required for these resources to be developed within the time frame required to meet future uranium demand.

The use of ionising radiation screening devices in airports

by T. Lazo*

Although the NEA generally focuses on radiological protection at nuclear power plants and related facilities, it also addresses other areas of radiological protection of interest to member countries. A particular subject of recent importance concerns the use of ionising radiation screening devices as part of airport security efforts.

Modern body scanners can produce human images that can be used to detect weapons that may be hidden beneath a person's clothing. Heightened concerns over terrorist threats to airline flights have prompted many countries to consider the use, or expanded use of body scanners. The use of such devices raises a wide series of questions, some of which concern the radiological protection of those who might be scanned. As such, the Inter-Agency Committee on Radiation Safety (IACRS),[1] an expert body in which the NEA works together with several other international organisations addressing radiological protection issues, recently developed a joint information paper laying out the key radiological protection and other issues that should be or have been considered when making decisions as to whether ionising radiation body scanners should be deployed in airports. This article provides an overview of the information paper.

Background

The failed attempt to blow up a plane from Amsterdam to Detroit on 25 December 2009 by the use of explosive powder sewn into the perpetrator's underwear has sparked new calls to step up security at airports. Much of the attention has focused on the new or increased use of body scanners that can reveal objects concealed beneath a passenger's clothing. Within the remit of radiological protection it should be considered whether those body scanner technologies using ionising radiation represent a health risk to the individuals being scanned and the operating personnel. In terms of possible public health impact, global airport traffic statistics indicate that the total number of air passengers is over 4.8 billion per year, and that international passenger traffic accounts for 42% of that global traffic. Therefore, the number of individuals who could be exposed to radiation might be significant, including screened people, employees who operate the security screening systems, employees who work nearby and other members of the general public.[2]

Key issues to be considered

From a radiological protection standpoint, any action or process that does or could cause radiation exposure of the public, workers or the environment must be justified, that is, must result in more good than harm, or it should not be allowed. Then, if it is justified, protection must be optimised: the amount of good that the action or process brings should be maximised with respect to the amount of harm it does or could cause by implementing protective actions.

In the particular case of airport body scanners, the radiological protection principle of justification suggests that a broad judgement will need to be made with respect to the balance between the radiological and other harms that may be caused, and the increased security that their use may bring. The harms to consider include radiological risks and social detriments. In terms of radiological risks, these include considerations of risks to those scanned, to workers operating the equipment, but also to "frequent flyers" and aircrew members who might be scanned frequently. Non-radiological harms to be considered include such questions as personal privacy or boarding efficiency issues. In addition, it may be relevant to consider the availability of security techniques that do not involve radiation exposure, yet could accomplish the same objective.

In terms of optimising protective actions, approaches that should be considered would include minimising the individual exposures received during a scan and choosing an "appropriate" frequency for scanning passengers. The latter might involve scanning all passengers systematically, scanning some fraction of passengers systematically or scanning a smaller number of passengers randomly.

Overall, these judgements tend to be very country-specific, and there is at this time no common view on whether the use of ionising radiation body scanners is or is not justified in a radiological sense. The following information, however, does provide a broad factual basis that can be used by governments and their regulatory organisations when deciding whether such scanners should be used.

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Description of commonly available technologies

Four types of body scanners are capable of detecting concealed items worn on a person's body and of indicating detection by means of an alarm. Two systems use machine-generated X-rays. A third system uses machine-generated, high-frequency, non-ionising radio waves. A fourth does not use any machine-generated radiation but detects the non-ionising radio waves naturally generated by the human body. In all cases, a human operator may be an integral part of the system, but newer systems process images automatically and humans need only be involved if suspicious objects are detected causing an alarm.

Individual body scanners based on two types of X-ray devices have been available for decades. Backscattered X-rays are used to image objects concealed beneath the passenger's clothing, while transmission X-rays can also image objects concealed within the body (for example swallowed, hidden in body cavities or implanted under the skin). Both technologies can produce high-quality still images in about 20-30 seconds.

The other types of commonly used body scanners are based on non-ionising technologies. They are currently available and have been in test use for some time. The current technologies include different non-ionising techniques using radio waves (millimetre-wave and terahertz imaging), or thermal and multi-band imaging. These techniques can only detect objects concealed beneath clothing. At present, the most developed and widespread technology is the millimetre wave, which can provide high-quality, still images in 3D in about 2-3 seconds.

Radiation exposure from X-ray body scanners

Body scanners based on non-ionising technologies do not expose the people being scanned to ionising radiation. X-ray body scanners will expose the people being scanned, although the dose to the scanned person is very low. Generally, the radiation dose to the scanned individual from a backscatter system will be much lower than the dose from a transmission system. Typically a single scan of an individual will result in the person receiving a radiation dose of 0.1 µSv from a backscatter X-ray scan, and about 5 µSv from a transmission X-ray scan. Radiation doses are cumulative, so an individual's total dose will depend on the number of scans performed (some passengers require four scans per screening procedure) and on the frequency with which the individual travels. To put this into perspective, during any single year, every individual on earth will be exposed to natural, background radiation to a level of, on average, about 3 000 µSv. In flight, galactic cosmic rays (GCRs) are a major source of radiation exposure to the aircrew and passengers, with dose rates significantly higher than at ground level. In-flight doses vary with flight path (latitude, altitude and duration) but, for the sake of comparison, the typical total effective dose due to GCRs for a transatlantic flight (e.g. from Europe to North America) is on the order of 50 µSv. In this context, radiation protection issues related to the use of X-ray body scanners should be assessed and balanced against the direct and indirect benefits of such scans as input to government decisions concerning their use.

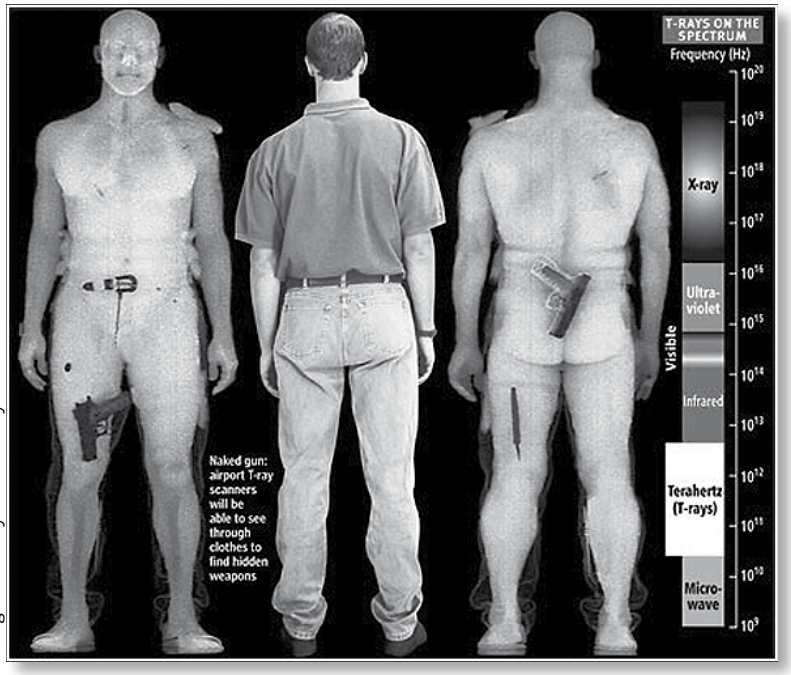

Image courtesy of the Daily Mail

Images from a terahertz scan showing the detection of hidden weapons.

Privacy issues

Privacy issues are a major concern in the use of body scanners, particularly in the case of backscatter systems since this technology produces an image of the naked human body. Measures are being taken to resolve these concerns by situating the personnel interpreting the images in a separate location, without contact with the person under inspection, and through the implementation of software to mask faces and private areas (in these cases image analysis may be automated). In some countries, the screener and the screened person have to be of the same gender, and in some countries children are not screened.

Radiological protection issues

In assessing the possible use of X-ray body scanners, there are two significant radiological protection issues that may be of relevance with regard to the government decision whether their use is justified. First, although the individual exposures are very low, the exposure experienced by the scanned population as a whole will depend on whether all passengers are systematically scanned, or alternatively whether passengers are selected for scanning randomly or on the basis of specific criteria. The manner in which passengers would be selected would need to be known in order to appropriately assess the full radiological protection impact of scanner use.

Second, the use of X-ray body scanners on sensitive groups, such as pregnant women and children, could be considered to present other hazards, and as such the use of scanners on these sensitive groups could be assessed separately during government consideration of justification.

Conclusions

It is not possible to make general statements about the rationale adopted when making national decisions to use X-ray body scanners or not. It can be said that most countries appear to have chosen not to use X-ray body scanners, but rather to use non-ionising radiation body scanners or other more "standard" search techniques (e.g. metal detectors, pat-down searches, etc.). In all these national choices, it appears that privacy issues have posed problems with these devices, irrespective of whether they use ionising radiation. It also appears that the simple fact that X-ray body scanners use radiation, even at extremely low individual levels, can raise significant concerns, which are being addressed by national radiological protection authorities. The IACRS information paper on this subject has clearly helped raise awareness of the pertinent issues and inform the debate.

Notes

1. The IACRS was established in 1990 to promote consistency and co-ordination of policies with respect to areas of common interest in radiological protection and safety. Areas of common interest to the IACRS members include applying principles, criteria and standards of radiological protection and safety and translating them into regulatory terms; coordinating research and development; advancing education and training; promoting widespread information exchange; facilitating the transfer of technology and know-how; and providing services in radiological protection and safety. For further information concerning the IACRS, see www.iacrs-rp.org/.
2. Airport Council International (ACI) member airports, representing approximately 98% of global airport traffic, have reported in the ACI Annual World Airport Traffic Reports (WATR) that the total number of passengers rose marginally in 2008 to 4.874 billion passengers, compared to 4.869 billion in 2007.

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Strategic aspects of nuclear and radiological emergency management

by B. Ahier*

Emergency situations demand that actions be taken by responsible organisations in a timely and effective manner to mitigate consequences for the population, infrastructure and the environment, and to support the return of affected areas to normal social and economic activity to the extent possible. To deliver an effective response over the emergency management timeline (see Figure 1), it is necessary to make, maintain and exercise adequate plans and arrangements in advance of an emergency situation. These must contain appropriate elements and resources for preparedness, response and assistance to identified threats, recognise and include all implicated partners, and take account of international interfaces. Effective management of complex emergency situations that can lead to a wide range of consequences and involve multiple organisations at the local, national and international levels also requires anticipation of the range of decision-making needs, an understanding of the interactions between response organisations and a model for their co-ordination.

Experience from managing emergency situations has shown that the integration of these factors into emergency preparedness and response arrangements should be based on a guiding strategic vision. Emergency response is a dynamic process that develops in time from a situation of little information to one of potentially overwhelming information. Within this context, emergency response organisations must be able to respond in an appropriate and timely manner at any point along the emergency management timeline. This will be facilitated by an overarching framework to guide the decision-making process.

To contribute to work in this area, the NEA Committee on Radiation Protection and Public Health (CRPPH) Working Party on Nuclear Emergency Matters (WPNEM) reviewed its collective experience to extract key themes that could form a strategy for improving decision-making in emergency management. This focused on the NEA International Nuclear Emergency Exercise (INEX) series, as well as experience from national emergency management programmes. Additionally, experience from the INEX-3 exercise (2005-2006) has shown that longer-term consequence management and the transition to recovery remain particularly challenging. As such, the WPNEM also focused on the development of strategies for countermeasures for managing the longer-term consequences of an emergency.

As decision-making is at the core of emergency management, the WPNEM developed a strategic framework to be considered by national emergency management authorities when establishing or enhancing processes for decision-making, and when developing or implementing protection strategies. The outcomes are presented in the report *Strategic Aspects of Nuclear and Radiological Emergency Management*.[1] The report provides insights into and a strategic basis for decision-making as an integral part of emergency management. Such a guiding strategic view, applied during preparedness, will enhance the management of complex emergency situations involving many organisations and stakeholders at the local, national and international levels.

Planning for effective decision-making

A strategic approach to decision-making can facilitate timely, effective and compatible decision-making by response organisations at every level within the emergency management structure and between countries, helping to ensure optimal protection of health, the environment and society during

Figure 1: Emergency management timeline and emergency phases

Preparedness	Response				Recovery
	Early		Intermediate		Late
Planning stage	Event/ response initiation	Crisis management	Consequence management	Transition to recovery (including recovery planning)	Recovery/long-term rehabilitation
	Emergency exposure situation				Existing exposure situation

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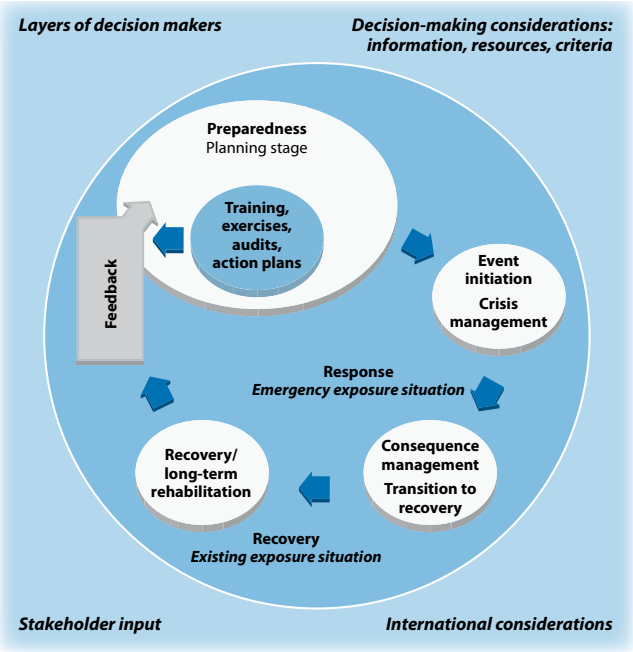
Figure 2:
Overview of the emergency management cycle



an emergency situation. Within this context, the first part of the report provides a framework of seven key elements for decision-making, briefly described below, which cover the emergency management timeline and help to identify and frame the relevant aspects that should be considered in formulating a decision.

Planning for decision-making within the emergency management cycle

Decision-making lies at the core of emergency management. Any strategy for decision-making needs to be placed coherently within the overall emergency management cycle: preparedness through response, recovery and post-event feedback (see Figure 2).

Depth of preparedness

The credible scenarios for which detailed planning should be undertaken are derived from a comprehensive threat and risk assessment that looks at all possible nuclear and radiological emergencies in terms of their origin, likelihood and magnitude of impacts. The outcomes of these assessments will provide an indication to emergency planners of the level of detail to which each scenario should be planned, either in whole or at different points in the timeline.

The emergency management structure and co-ordination of decision-making

Different organisations in different jurisdictions will have a role in the emergency management cycle. A key aspect of decision-making is therefore co-ordination of the various decision-making processes among all the organisations involved at the local, national and international levels. Co-ordination of arrangements and responsibilities for decision-making across jurisdictions for different scenarios is therefore important. The goal is to have the approaches to decision-making, and the resulting decisions, as compatible as practical across the spectrum of the response to ensure optimal protection of health, the environment and society.

Identifying and characterising key decision-making points

Anticipating, identifying and characterising the key decision-making points along the emergency timeline is critical to successful planning for emergency situations. These include the types and timelines of likely decisions, and their characteristics such as the inputs necessary for establishing an initial technical basis for recommendations, the outputs and the linkages to other response partners and stakeholders.

Co-ordinated communications

The co-ordination of decision-making both nationally and internationally, amongst all parties implicated in the response, is critical. Effective communications and co-ordination will facilitate compatible decision-making.

Appropriate and timely decision-making

While the threat and risk assessment will identify the types of scenarios for which detailed plans should be elaborated, each emergency will have its own characteristics. Decisions must match the characteristics of the particular emergency. Processes that facilitate the development of situation-specific recommendations are critical, because an appropriate decision for one emergency may be different in another situation.

Stakeholder involvement

Complex emergency situations require the involvement of a broad range of stakeholders to facilitate their effective management. Emergency planners and decision-makers should identify the range of relevant stakeholders and how their involvement may impact the effectiveness of decisions and the implementation of protection strategies. Relevant stakeholders, either directly or through their representatives, should be included in the emergency planning arrangements.

Consequence management and transition to recovery

In addition to mitigating the impacts on the population, infrastructure and the environment, planning for the emergency response includes the

ultimate goal of returning affected areas to normal social and economic activity to the extent possible. This goal will present significant challenges not only to affected populations, but also to the organisations responsible for the emergency management and recovery activities in countries directly or indirectly affected by the event. Meeting this goal will be facilitated by effective and co-ordinated management of the consequences and the transition to recovery, which will set the context (including socio-economic aspects) for the long-term recovery. Management strategies that are developed and implemented as part of emergency preparedness will improve decision-making throughout the emergency response.

In this context, the second part of the report on strategic aspects of emergency management provides a framework for planning and implementing protection strategies as part of consequence management and the transition to recovery, focusing on those areas of interest identified in the INEX-3 exercise. A key aspect of these later phases of the emergency timeline is that the actual situation may be quite difficult to predict in detail in advance. As such, while protection strategies for the early phase of an emergency situation may be relatively straightforward to characterise and to prepare for an identified scenario, protection strategies for later periods following the emergency's onset become increasingly difficult to plan in detail during the preparedness phase.

For this reason, it is important to plan structures and strategies for later-phase consequence and recovery management rather than specific actions. This does not mean that detailed pre-planning is unnecessary, but rather that preparedness should focus on identifying the types of response areas and needed actions rather than their specific details.

Building on the previously described framework for decision-making, the framework described below addresses those aspects of consequence management and the transition to recovery that can most effectively be planned in advance. It is hoped that they will find applicability amongst national emergency management authorities and international organisations by providing insights into key considerations for planning and implementing protection strategies, specifically in the development of necessary plans, procedures and arrangements.

Building the emergency management structure for consequence management and recovery

During the preparedness phase, it is important to identify, co-ordinate and define the roles and responsibilities of the emergency management structure for consequence management and for recovery. This includes building partnerships with identified organisations and jurisdictions for planning and implementing a co-ordinated response, developing and implementing protection strategies, coordinating recovery objectives and strategies, and implementing strategies for co-ordinated international communication facilitating compatible decision-making.

Dealing with the consequence management phase

As part of preparedness, responsible organisations should use the threat and risk assessment to identify potential impacts and possible countermeasures for each credible scenario. Optimised protection strategies for consequence management and the transition to recovery should be developed prior to an emergency in co-ordination with all relevant parties. During an emergency, decision-makers should be advised on appropriate courses of actions throughout the consequence management and transition to recovery phases. Countermeasures should be terminated when successfully implemented, no longer applicable, or when event changes indicate the need for different approaches or countermeasures.

Managing the transition to recovery

It is important to identify potential issues that will need to be addressed during the long-term recovery after an emergency. To support this, a basic framework recovery plan should be developed as part of preparedness, with common issues to facilitate the recovery operations, for detailed elaboration in response to a specific emergency. This will include a description of roles, responsibilities, priorities, timelines and financial implications.

Developing and maintaining processes for stakeholder involvement

Planners should identify and involve all relevant stakeholders in emergency preparedness in order to improve the development and implementation of appropriate protection strategies and the transition to recovery.

Conclusion

It is hoped that consideration by emergency planners and decision-makers of the frameworks presented in the report will facilitate compatible and/or consistent approaches to consequence management and recovery amongst the multiple layers of organisations and entities, nationally and internationally, involved in responding to emergency situations. *Strategic Aspects of Nuclear and Radiological Emergency Management* may be downloaded free of charge on the NEA website at www.nea.fr.

Note

1. The WPNEM gratefully acknowledges the work of its three expert groups that developed different aspects of this report, and thanks the group chairs – Mr. B. Powell (United Kingdom), Ms. C. McMahon (Ireland), Mr. F. Ugletveit (Norway) – and the expert groups members for their contributions.

Advanced reactor experimental facilities

by A. Amri, J. Papin, J. Uhle and C. Vitanza*

For many years, the NEA has been examining advanced reactor issues and disseminating information of use to regulators, designers and researchers on safety issues and research needed. Following the recommendation of participants at an NEA workshop, a Task Group on Advanced Reactor Experimental Facilities (TAREF) was initiated with the aim of providing an overview of facilities suitable for carrying out the safety research considered necessary for gas-cooled reactors (GCRs) and sodium fast reactors (SFRs), with other reactor systems possibly being considered in a subsequent phase. The TAREF was thus created in 2008 with the following participating countries: Canada, the Czech Republic, Finland, France, Germany, Hungary, Italy, Japan, Korea and the United States. In a second stage, India provided valuable information on its experimental facilities related to SFR safety research.

Study method

The TAREF members decided to build on the experience of a similar NEA activity described in *Nuclear Safety Research in OECD Countries: Support Facilities for Existing and Advanced Reactors* (SFEAR). The study method adopted entailed first identifying high-priority safety issues that require research and then categorising the available facilities in terms of their ability to address the safety issues.

The Task Group also agreed that the GCR-related task could be completed at an earlier stage than the SFR task given that a significant part of the safety issues to be addressed had already been compiled in an earlier United States Nuclear Regulatory Commission (USNRC) exercise (called the Phenomenon Identification and Ranking Tables – PIRT). Hence, two separate reports were produced for the GCR and SFR tasks. These reports are summarised below.

Approach for GCRs

The Task Group followed an approach similar to that performed by the USNRC for the PIRT, and identified the following technical areas for consideration: accidents and thermo-fluids (including neutronics), fission product transport, high-temperature metallic materials, graphite and ceramics, and fuel [tristructural-isotropic (TRISO) and other fuel types]. In the case of structural materials, graphite and ceramics experience can be broader than nuclear and was considered to the degree possible. Other technical areas such as seismic assessment (except for potential consequences on core compaction), fire safety, instrumentation and control, and human and organisational factors were not treated in the report since the issues are not specific to GCRs.

For each of the above technical areas, the TAREF members identified the safety issues still requiring research. Only the issues identified as being of high importance to safety and for which the state of knowledge is "low" or "medium" were included in the discussions.

Approach for SFRs

Based on discussions and the results of a questionnaire, the TAREF members identified the following technical areas to be addressed for SFRs: thermo-fluids, fuel safety, reactor physics, severe accidents, sodium risks, structural integrity and other issues. The first four technical areas address phenomena and issues specific to the nuclear industry. The other areas address phenomena that are relevant for the nuclear industry, but for which experience may be broader than nuclear.

In a similar way, seismic assessment (except for potential consequences on core compaction), instrumentation and control, and human and organisational factors were not treated since they are not specific to the nuclear industry, and within the nuclear area, are not specific to SFRs. Other technical areas such as fuel fabrication, fuel handling and irradiated material investigation techniques (as used in hot cell facilities) were not considered as they are more related to operational concerns or not specific to SFRs.

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For each of the above technical areas, the task members agreed on a set of safety issues requiring research and established a ranking with regard to safety relevance (high, medium, low) and the status of knowledge based on the following scale relative to full knowledge: high (100%-75%), medium (75-25%) and low (25-0%). As for GCRs, only the issues identified as being of high safety relevance and for which the state of knowledge is low or medium were included in the discussion, as these issues would likely warrant further study.

Safety issues and suitable experimental facilities

For each of the safety issues, the TAREF members identified appropriate facilities, providing relevant information such as operating conditions (in- or out-of-reactor), operating range, description of the test section, type of testing, instrumentation, current status and availability, and uniqueness. Based on the information collected, the task members assessed prospects and priorities for GCR and SFR safety research and developed recommendations as to priorities and options for facility utilisation through international programmes. In particular, the group agreed on the main criteria for priority setting, which was based on the following items (high, medium or low for each):

- Relevance of the facility to cover a specific issue.
- Uniqueness (e.g. one-of-a-kind for in-pile testing).
- Availability for addressing the issue. Due to the specific context of SFR development with significant R&D activity during the period 1970-1995, followed by a period of reduced effort and now restarting in several countries, three time windows were considered: 0-3 years, 4-8 years and more than 8 years.
- Readiness (e.g. staff availability to run it).
- Operating cost (<0.3, 0.3-1, >1 million USD) or construction cost (<0.5, 0.5-2, >2 million USD).

The group rated those facilities that were costly either to operate or to construct as being ranked high in this category as they were more suitable to host a multilateral co-operative programme than facilities of lower cost which could be supported by one country alone. TAREF members who had proposed facilities were requested to characterise the latter according to the above criteria. Based on this information, the following conclusions and recommendations were developed.

Conclusions and recommendations

1. The TAREF activity proved to be a useful exercise for achieving consensus on the technical areas and issues related to the safety of GCR and SFR systems, as well as for identifying a number of facilities that are or will become available in OECD/NEA member countries for supporting GCR and SFR safety research.
2. Existing facilities and facilities that are being constructed or planned in member countries cover all technical areas of concern and most of the safety issues identified in these areas. Hence, there is no apparent need for the NEA Committee on the Safety of Nuclear Installations (CSNI) to consider building a facility beyond what is currently planned in member countries. However, due to the specific context of SFR development, a large number of facilities operating in the past with sodium as coolant are no longer available

JAEA

The High-temperature Engineering Test Reactor (HTTR) in Japan.

or have been converted to address water reactor issues. This explains why for SFRs, the availability of relevant facilities for all technical areas is limited in the short term, and that the decision to restart or to modify some facilities is under consideration. This situation also led the group to rank the facilities over three time windows up to the long term (beyond eight years from now).

3. Based on the responses received, the highest-ranked facilities were identified. For SFRs, these facilities are considered for the short, mid- and long term; it should be noted, however, that the availability of facilities under construction or to be restarted or refurbished cannot be guaranteed at a given date. Facilities available in the short term are assumed to be available in the mid- and long term, and facilities available in the mid-term are assumed to be potentially available in the long term.

Recommendations specific to GCRs

4. The Japanese High-temperature Engineering Test Reactor (HTTR) constitutes a unique resource in that it is the only experimental high-temperature GCR available for a test programme in OECD/NEA member countries. It is a graphite-moderated, helium-cooled reactor that can reach temperatures as high as 1 600°C in some transient conditions. The experiments planned to study the effects of reactor cavity cooling system (RCCS) performance reduction are highly relevant for GCR safety assessments. The HTTR is also suitable for neutronics, fission product release and graphite dust issues related to prismatic fuel arrangements. Actions should be taken to develop an international programme focused on the HTTR's capabilities and on the safety issues identified by the TAREF.

5. The Czech High-temperature Helium Loop (HTHL) offers the opportunity to host separate-effect tests carried out both out of pile and in pile, hence offering the flexibility to address studies in which the combined effect of a high-temperature gas environment and radiation is relevant, for example fission product transport or high-temperature materials behaviour.

6. The HTTR and the HTHL plans are suitable for near-term initiatives, i.e. for proposals that could result in defining an experimental programme in a one- to two-year time frame. Following current practice for OECD/NEA joint projects, such initiatives depend on the proposal from the host country and facility as well as the co-operative support from other member countries. NEA support to set up such programmes will be required.

7. The French *Commissariat à l'énergie atomique* (CEA) is encouraged to keep the CSNI and relevant CSNI working groups abreast of the gas fast reactor (GFR) design developments and the analytical and experimental progress to support such development, including proposals for specific experimental programmes when appropriate. In particular, the CEA should provide updates related to its long-term plans for the GFR demonstration reactor (ALLEGRO), which in the long term (approximately ten years) could constitute a focus for joint international efforts.

Recommendations specific to SFRs

8. The TAREF members agreed that for new SFR projects, the most important R&D safety needs concern the following technical areas in order of priority: fuel safety and severe accident issues are of prime interest due to the lack of knowledge on new pin design and materials; thermo-fluids and core physics issues are of second priority as current knowledge is deemed roughly sufficient when margins for uncertainties are taken into account; sodium risks and structural integrity issues may be considered as third priority as they are more design-dependent.

9. The need for fuel pin irradiation capabilities under representative conditions of fast neutron flux has been identified as a crucial point for addressing safety issues of high priority.

10. In the short term, the Indian Fast Breeder Test Reactor (FBTR) can be a valuable resource for irradiation of SFR fuel pins and to generate new materials data; the American Annular Core Research Reactor (ACRR) could address issues related to fuel safety and severe accidents under specific conditions. In addition, the German KASOLA facility could provide data for the thermo-fluids issues apparent in computational fluid dynamics (CFD) modelling approaches. The Japanese SWAT-1R-3R facility can be appropriate for studying sodium water interaction in steam generator units; the Indian SFTF facility can be valuable for addressing several issues related to sodium fires; the American SURTSEY facility can be relevant for studies on sodium fires and sodium-water interaction in steam generators.

11. In the mid-term, the Japanese fast neutron reactor JOYO was identified as suitable to address fuel safety issues related to new fuel pin designs (fuel pin performance and new materials performance under irradiation, margin to fuel melting and impact of use of minor actinides) and certain other issues; however, uncertainty still exists as the decision for the possible repair and operating schedule has not yet been made. Severe accident issues can only be addressed in a comprehensive way from the mid-term to the long term, due to the lack of available facilities for simulation of representative transient conditions in the short term with irradiated fuel pins. The Kazakh IGR facility used for JAEA programmes and addressing fresh fuel (controlled fuel relocation and debris bed formation) may be a suitable option in the mid-term as plans are under considera-

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The Fast Breeder Test Reactor (FBTR) in India.

tion for it to handle irradiated fuel. The French VULCANO can also help for severe accident issues, provided it is refurbished for sodium use. The American TREAT experimental reactor was also considered in the mid-term for its relevance to severe accidents issues (past experimental programmes simulating fast power transients), but restart of the facility has not yet been decided (the decision is expected in 2010). In addition, the French MASURCA reactor may be suitable for core physics issues for providing improved nuclear data of core materials (in relation with high burn-up levels and the use of minor actinides) and associated uncertainties.

12. In the long term, the French ASTRID SFR prototype, although at first designed as an industrial prototype to be transposed to a future first-of-a-kind commercial reactor, will offer some irradiation capabilities and may address mainly fuel performance issues (new cladding materials tests and impact of minor actinides under fast flux). The French Jules Horowitz Reactor (JHR), under construction and designed for material testing, may address fuel safety issues (new materials performance under irradiation, impact of use of minor actinides and slow transients under specific conditions). Availability for initial testing is foreseen in 2017-2020. The French CABRI experimental reactor was recognised by the group members as the most appropriate facility to address irradiated fuel behaviour under operational and accident conditions (fuel safety issues such as margins for fuel melting and deterministic pin failure, severe accident issues such as consequences of various accidents leading to fuel melting, with associated consequences and risk of critical events and energy release). The facility may be available for testing from 2020 (after completion of LWR safety research programmes). In the case of innovative design for secondary circuits, the Italian LIFUS5 facility would address sodium interaction with alternative coolant species.

Finally, it is recommended that relevant CSNI working groups should be encouraged to share modelling information and to discuss modelling activities relevant for GCR and SFR safety, in order to help focus the potential test programmes and/or to enhance the data utilisation for model development. In addition, the CSNI is to maintain an adequate level of exchange with the CNRA regarding needs and initiatives in the GCR and SFR safety areas.

OECD/NEA joint projects

As a result of the TAREF activity, an OECD/NEA joint project was proposed by the Japan Atomic Energy Agency (JAEA) and is being set up at the JAEA High-temperature Engineering Test Reactor (HTTR). The objectives of the proposed project are to conduct integrated, large-scale test of loss of forced cooling (LOFC) in the JAEA HTTR, to examine high-temperature, gas-cooled reactor (HTGR) safety characteristics in support of regulatory activities, and to provide data useful for code validation and improvement of simulation accuracy. The reactor performance under accidental conditions considered in the Phenomena Identification Ranking Tables (PIRT) set up by the USNRC will be assessed in this project.

It is expected that other OECD/NEA joint projects may be initiated based on the recommendations stemming from the TAREF activity. In particular, joint projects addressing first-priority SFR safety issues might be initiated within two or three years.

10th session of the International School of Nuclear Law

by S. Kuş*

This summer, from 23 August until 3 September 2010, the Nuclear Energy Agency in co-operation with the University of Montpellier 1 will hold the 10th anniversary session of the International School of Nuclear Law (ISNL).

During the past nine years, the ISNL has trained more than 500 participants from all around the world, many of whom are still active in the nuclear field. Each session brings together between 55 and 60 participants from both developed and developing countries to take part in an intensive academic and practical training programme in the South of France, at one of the oldest law faculties in Europe.

The idea to establish the school was the result of many factors, most importantly the fact that education in nuclear law was, even in countries with substantial nuclear power programmes, practically non-existent. Universities were largely disinterested and nuclear institutions, both public and private, did not take any initiatives to fill the gap. Mr. Patrick Reyners, at that time Head of NEA Legal Affairs, proposed to establish an education programme in this field with several colleagues; he was encouraged by the NEA's Management to set up such an institution linked to a university. Since 2001, the NEA has organised annual sessions in co-operation with the University of Montpellier 1. From the very beginning, Mr. Reyners and Mrs. Odette Jankowitsch-Prevor, former senior lawyer at the International Atomic Energy Agency, have served as both tutors and lecturers at the school, guiding participants through the sessions with both patience and good humour. As of 2011, they will entrust this task to other hands, but the NEA will always remain grateful for the time, energy and dedication which they have devoted to this important activity.

The two-week course takes place each year at roughly the same period (end of August/beginning of September). Highly renowned specialists deliver lectures, in English, on virtually all aspects of international nuclear law, i.e. international institutions; protection against ionising radiation; nuclear safety and nuclear accident management; non-proliferation of nuclear weapons and safeguards; nuclear security; transport of nuclear material and fuel; management of spent fuel and radioactive waste; liability, compensation and insurance for nuclear damages; environmental protection; and international trade in nuclear material and equipment. In addition, participants are encouraged to engage fully in the question and answer sessions following each lecture and are divided into small groups to examine the various case studies that are presented in connection with most of the subjects covered.

Over the years, the course has evolved and integrated new components into the programme. For example, both the response to the nuclear terrorism threat and the impact of environmental laws on nuclear activities have been integrated in recent years. In addition, the closing lecture of each session includes a special guest who addresses the participants on a particularly timely topic, such as global initiatives in pursuit of the non-proliferation of nuclear weapons or the legal implications of engaging in a nuclear power programme for the first time.

Subsequent to each session, an optional diploma programme may be pursued by candidates, constituting an ideal opportunity for professionals to acquire an academic degree in this highly specialised field. Independent of its teaching role, the school serves as a forum for participants to meet both professional and academic colleagues from around the world in a convivial atmosphere. Following the sessions, participants usually use the co-operation and networking opportunities which the ISNL offers to stay in contact for professional activities and social networking. The NEA facilitates communication between all former participants by keeping their co-ordinates up-to-date in the ISNL Alumni database.

In celebration of the 10th anniversary of the ISNL, the NEA will dedicate a special publication to the school containing scholarly papers which reflect the ISNL's teaching programme in the various fields of international nuclear law.

More information is available at www.nea.fr/law/isnl/.

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Nuclear power in NEA member countries

Situation and projections as of 31 December 2009

At the end of 2009, the total nuclear generating capacity of the 340 reactors connected to the grid in NEA member countries was 308.8 gigawatts (GWe). Another 14 reactors totalling 14.6 GWe were under construction and 24 reactors totalling 31.2 GWe were firmly committed. These preliminary data and other statistics on fuel cycle capacities and requirements are provided in the latest edition of *Nuclear Energy Data*, as well as short country reports on important trends and issues.

Nuclear generating capacity (net GWe) and percentage of total electricity generating capacity (a)

Country	2009		2010		2020		2030	
	Nuclear	%	Nuclear	%	Nuclear	%	Nuclear	%
Belgium (c)	5.9	36.9	5.9	34.3 - 33.7	5.9 - 6.0	26.8 - 22.2	0.0 - 5.9	0.0 - 19.7
Canada	12.1	10.3 (b)	11.4 - 13.6	9.6 - N/A	11.4 - 15.3	8.7 - N/A	N/A	N/A
Czech Republic	3.6	19.7	3.7 - 3.8	19.8 - 20.4	3.8 - 5.9	20.8 - 30.7	7.4	37.6 - 36.5
Finland	2.7	21.4	2.7	21.4	4.3	29.9	3.8	29.0
France	63.1	52.5	63.1	52.1 - 51.7	66.3	N/A	N/A	N/A
Germany	20.4	13.8 (b)	20.4	15.8 - 15.2	3.5	2.6 - 2.4	0.0	0.0 - 0.0
Hungary	1.9	21.7	1.9	23.0 - 21.9	1.9	21.5 - 17.2	1.9	21.0 - 17.4
Japan (d, e)	47.0	19.7 (b)	N/A	N/A	N/A	N/A	N/A	N/A
Korea	17.7	24.1	18.7	24.6	30.9	30.9	42.7	40.6
Mexico	1.4	2.7	1.4 - 1.6	N/A	N/A - 1.6	N/A	N/A - 1.6	N/A
Netherlands	0.5	1.9	0.5	1.8	0.5	1.4	0.5	1.4 - 1.2
Slovak Republic	1.7	25.4	1.8	25.0	2.8 - 4.3	35.0 - 40.6	2.9 - 4.3	30.2 - 35.0
Spain	7.4	7.6	7.4	7.5	6.9	5.4	N/A	N/A
Sweden	9.3	26.7	10.1 - N/A	N/A	10.1 - N/A	N/A	10.1 - N/A	N/A
Switzerland (b)	3.2	18.7	3.2 - N/A	18.7 - N/A	3.2 - N/A	17.7 - N/A	3.9 - N/A	20.7 - N/A
United Kingdom (b)	10.1	12.6	10.5	11.9 - 11.8	4.4 - 5.8	5.0 - 6.5	N/A	N/A
United States	100.8	10.0	101.6	9.7	110.9 - 112.6	10.7 - 10.4	110.9 - 126.7	10.2 - 10.9
Total/average	**308.8**	**12.9**	-	-	-	-	-	-

(a) Including electricity generated by the user (autoproduction) unless stated otherwise.
(b) Provisional data.
(c) By law, Belgium's nuclear power plants must be retired from service after 40 years of operation, with the exception of the three oldest in the fleet (Doel 1 and 2 and Tihange 1) which received a one-time, ten-year extension.
(d) For fiscal year.
(e) Gross data converted to net by the Secretariat.
N/A Not available.

Status of nuclear power plants and corresponding capacity (net GWe)

Country	Connected to the grid		Under construction		Firmly committed*		Planned shutdown**	
	Units	Capacity	Units	Capacity	Units	Capacity	Units	Capacity
Belgium	7	5.9	-	-	-	-	-	-
Canada	17 (a)	12.1	-	-	-	-	-	-
Czech Republic	6	3.6	-	-	-	-	-	-
Finland	4	2.7	1	1.6	-	-	-	-
France	58	63.1	1	1.6	1	1.6	-	-
Germany	17	20.4	-	-	-	-	6	6.1
Hungary	4	1.9	-	-	-	-	-	-
Japan (e)	54	47.0	3	2.9	12	15.9	-	-
Korea	20	17.7	6	6.5	2	2.7	-	-
Mexico	2	1.4	-	-	-	-	-	-
Netherlands	1	0.5	-	-	-	-	-	-
Slovak Republic	4	1.7	2 (d)	0.8	-	-	-	-
Spain	8	7.4	-	-	-	-	-	-
Sweden	10	9.3	-	-	-	-	-	-
Switzerland	5	3.2	-	-	-	-	-	-
United Kingdom (c)	19	10.1	-	-	-	-	4	1.4
United States	104	100.8	1 (b)	1.2	9	11.0	-	-
Total	**340**	**308.8**	**14**	**14.6**	**24**	**31.2**	**12**	**8.0**

(a) Does not include three units currently under refurbishment (Point Lepreau and Bruce A units 1 and 2).
(b) Watts Bar 2 construction resumed.
(c) Provisional data.
(d) Mochovce 3 and 4 construction resumed.
(e) Gross data converted to net by the Secretariat.
* Plants for which sites have been secured and main contracts placed.
** Plants expected to be retired from service by the end of 2013.

New publications

General interest

Annual Report 2009

ISBN 978-92-64-99126-2. 52 pages. Free: paper or web.

Generation IV International Forum

Proceedings, GIF Symposium, Paris, France, 9-10 September 2009

ISBN 978-92-64-99115-6. 296 pages. Free: paper or web.

The Generation IV International Forum (GIF), initiated in 2000, is an international co-operative endeavour organised to carry out the research and development (R&D) needed to establish the feasibility and performance capabilities of the next-generation nuclear energy systems. Eight ambitious goals have been defined for Generation IV systems in four main areas: sustainability, economics, safety and reliability, and proliferation resistance and physical protection. They are shared by a large number of countries as they aim at responding to the economic, environmental and social requirements of the 21st century. These goals provided the basis for identifying and selecting six nuclear energy systems for further development. The six systems selected employ a variety of reactor, energy conversion and fuel cycle technologies. Their designs feature thermal and fast neutron spectra, closed and open fuel cycles and a wide range of reactor sizes from very small to very large. To increase the visibility of the technical work performed to date under the GIF, it was decided to hold a GIF Symposium in September 2009 open to the wider Generation IV scientific and industrial community. The objective of this first GIF Symposium was to provide a well-documented overview of the initiative and an opportunity to examine the most significant technical progress and evolution in the different areas since the Forum's inception.

Nuclear Energy and Addressing Climate Change

Brochure. 8 pages. Free: paper or web.

Nuclear Energy Technology Roadmap

Brochure. 48 pages. Free: paper or web.

This nuclear energy roadmap has been prepared jointly by the International Energy Agency (IEA) and the OECD Nuclear Energy Agency (NEA). Unlike most other low-carbon energy sources, nuclear energy is a mature technology that has been in use for more than 50 years. The latest designs for nuclear power plants build on this experience to offer enhanced safety and performance, and are ready for wider deployment over the next few years. Several countries are reactivating dormant nuclear programmes, while others are considering nuclear for the first time. In the longer term, there is great potential for new developments in nuclear energy technology to enhance the role of nuclear power in a sustainable energy future.

Economic and technical aspects of the nuclear fuel cycle

Projected Costs of Generating Electricity

2010 Edition

ISBN 978-92-64-08430-8. 216 pages. Price: € 70, US$ 98, £ 63, ¥ 9 100.

This joint report by the International Energy Agency (IEA) and the OECD Nuclear Energy Agency (NEA) is the seventh in a series of studies on electricity generating costs. It presents the latest data available for a wide variety of fuels and technologies, including coal and gas (with and without carbon capture), nuclear, hydro, onshore and offshore wind, biomass, solar, wave and tidal as well as combined heat and power. It provides levelised costs of electricity (LCOE) per MWh for almost 200 plants, based on data covering 21 countries (including four major non-OECD countries), and several industrial companies and organisations. For the first

time, the report contains an extensive sensitivity analysis of the impact of variations in key parameters such as discount rates, fuel prices and carbon costs on LCOE. Additional issues affecting power generation choices are also examined. The study shows that the cost competitiveness of electricity generating technologies depends on a number of factors which may vary nationally and regionally. Readers will find full details and analyses, supported by over 130 figures and tables, in this report which is expected to constitute a valuable tool for decision makers and researchers concerned with energy policies and climate change.

Public Attitudes to Nuclear Power

ISBN 978-92-64-99111-8. 56 pages. Free: paper or web.

Public attitudes to nuclear power are critical in shaping nuclear policies in OECD/NEA countries and the latter will only be able to make use of this energy source if a well-informed public considers that its benefits outweigh its risks. This report provides a number of insights into public attitudes towards nuclear power. Support for nuclear energy is generally correlated with the level of experience of and knowledge about nuclear power. Interestingly, while the public is generally aware of the contribution of nuclear power to ensuring security of energy supply, its potential contribution to combating climate change is less well recognised. Solving the waste disposal issue would also significantly increase the level of public support. Furthermore, OECD/NEA member country governments may wish to reflect carefully on how to react to these results as, according to the surveys, they are the least trusted source on energy issues, far behind regulators, non-governmental organisations and scientists.

Nuclear safety and regulation

CSNI Technical Opinion Papers – No. 12

Research on Human Factors in New Nuclear Plant Technology

ISBN 978-92-64-99116-3. 40 pages. Free: paper or web.

It is a dynamic time for the nuclear power sector. Existing reactor control rooms are undergoing various forms of modernisation. New reactors are being built in many countries and advanced reactors are being designed through international co-operation to support power generation for decades to come. The new technologies and concepts that are being considered in this context could impact upon the roles of the plant operators and thus plant safety. It is therefore important that the potential implications – both positive and negative – are evaluated and understood. Through this technical opinion paper, the NEA Committee on the Safety of Nuclear Installations (CSNI) has sought to identify a set of research topics that should be explored in order to enhance knowledge of the human and organisational factors concerned. Research to address the topics described in this paper will provide the technical basis to help ensure that the benefits of new technology are realised and that the potential negative effects are minimised. This paper should be of particular interest to research organisations and other stakeholders (including regulatory agencies, international organisations and industry organisations) that could support this research and benefit from its results.

Experimental Facilities for Gas-cooled Reactor Safety Studies

Task Group on Advanced Reactor Experimental Facilities (TAREF)

ISBN 978-92-64-99110-1. 88 pages. Free: paper or web.

This report provides an overview of experimental facilities that can be used to carry out nuclear safety research for gas-cooled reactors and identifies priorities for organising international co-operative programmes at selected facilities. The information has been collected and analysed by a Task Group on Advanced Reactor Experimental Facilities (TAREF) as part of an ongoing initiative of the NEA Committee on the Safety of Nuclear Installations (CSNI) which aims to define and to implement a strategy for the efficient utilisation of facilities and resources for Generation IV reactor systems.

Experiments and CFD Code Application to Nuclear Reactor Safety (XCFD4NRS)

Workshop Proceedings, Grenoble, France, 10-12 September 2008

Free: CD-ROM or web.

Computational fluid dynamics (CFD) is to an increasing extent being adopted in nuclear reactor safety (NRS) analyses as a tool that enables a better description of specific safety-relevant phenomena occurring in nuclear reactors. The NEA Committee on the Safety of Nuclear Installations (CSNI) has in recent years conducted important activities in the CFD area, including the organisation of two workshops. The “XCFD4NRS” workshop was the second in the series and was held in Grenoble, France in September 2008. A total of 147 experts from 22 countries took part. These proceedings contain the five keynote lectures, summaries of the activities of three CFD writing groups and the 59 technical papers presented at the workshop.

Nuclear Fuel Behaviour under Reactivity-initiated Accident (RIA) Conditions

State-of-the-art Report

ISBN 978-92-64-99113-2. 208 pages. Free: paper or web.

Considerable experimental and analytical work has been performed in recent years which has led to a broader and deeper understanding of phenomena related to reactivity-initiated accidents (RIAs). Further, newly designed fuels – such as mixed-oxide (MOX) fuel and rods with new cladding – have been introduced which might behave differently than those used previously, both under normal operating conditions and during transients. Compared with 20 years ago, fuel burn-up has been significantly increased. These and other factors have led the NEA Committee on the Safety of Nuclear Installations (CSNI) and its Working Group on Fuel Safety to produce this state-of-the-art report. The report should be of particular interest to nuclear safety regulators, nuclear plant operators and fuel researchers.

Radioactive waste management

Applying Decommissioning Experience to the Design and Operation of New Nuclear Power Plants

ISBN 978-92-64-99118-7. 56 pages. Free: paper or web.

Experience from decommissioning projects suggests that the decommissioning of nuclear power plants could be made easier if it received greater consideration at the design stage and during the operation of the plants. Better forward planning for decommissioning results in lower worker doses and reduced costs. When appropriate design measures are not taken at an early stage, their introduction later in the project becomes increasingly difficult. Hence, their early consideration may lead to smoother and more effective decommissioning. It is now common practice to provide a preliminary decommissioning plan as part of the application for a licence to operate a nuclear facility. This means, in turn, that decommissioning issues are being considered during the design process. Although many design provisions aiming at improved operation and maintenance will be beneficial for decommissioning as well, designers also need to consider issues that are specific to decommissioning, such as developing sequential dismantling sequences and providing adequate egress routes. These issues and more are discussed in this report.

Cost Estimation for Decommissioning

An International Overview of Cost Elements, Estimation Practices and Reporting Requirements

ISBN 978-92-64-99133-0. 80 pages. Free: paper or web.

This report is based on a study carried out by the NEA Decommissioning Cost Estimation Group (DCEG) on decommissioning cost elements, estimation practices and reporting requirements. Its findings indicate that cost methodologies need to be updated continuously using cost data from actual decommissioning projects and hence, systematic approaches need to be implemented to collect these data. The study also concludes that changes in project scope may have the greatest impact on project costs. Such changes must therefore be identified immediately and incorporated into the estimate. Finally, the report notes that more needs to be done to facilitate the comparison of estimates, for example by providing a reporting template for national estimates.

Decommissioning Considerations for New Nuclear Power Plants

ISBN 978-92-64-99132-3. 16 pages. Free: paper or web.

Experience from decommissioning projects suggests that the decommissioning of nuclear power plants could be made easier if this aspect received greater consideration at the design stage and during operation of the plants. Better forward planning for decommissioning results in lower worker doses and reduced costs. When appropriate design measures are not taken at an early stage, their introduction later in the project becomes increasingly difficult. Hence, their early consideration may lead to smoother and more effective decommissioning operations. This report provides an overview of key decommissioning issues which are useful to consider when designing new nuclear power plants.

Il Decommissioning degli Impianti Nucleari

Si può, ed é stato fatto

Brochure. 8 pages. Free: paper or web.

More than Just Concrete Realities: The Symbolic Dimension of Radioactive Waste Management

ISBN 978-92-64-99105-7. 36 pages. Free: paper or web.

Key concepts of radioactive waste management, such as safety, risk, reversibility and retrievability, carry different meanings for the technical community and for non-technical stakeholders. Similarly, socio-economic

concepts, including community, landscape and benefit packages, are interpreted differently by diverse societal groups. Opinions and attitudes are not simply a faithful reflection of decision-making, actual events and communicated messages; perceptions and interpretations of events and objects also play a role. This report presents key issues and examples in order to build awareness of the importance of symbols and symbolism in communicating about perceptions and interpretations. It adds to the recognition that dialogue amongst stakeholders is shaped by dimensions of meaning that reach beyond dictionary definitions and are grounded in tradition and social conventions. A better understanding of these less obvious or conspicuous realities should help find additional ways of creating constructive relationships amongst stakeholders.

Optimisation of Geological Disposal of Radioactive Waste

National and International Guidance and Questions for Further Discussion

ISBN 978-92-64-99107-1. 28 pages. Free: paper or web.

As national geological disposal programmes progress towards implementation, the concept of "optimisation" and related requirements are receiving increased attention. Exchanges within NEA expert groups have shown that both regulators and implementers would benefit from a review of the relevant concepts and available guidance and experience. This report summarises and reviews the concepts relevant to the "optimisation" of geological disposal systems as they are outlined in national and international guidance. It also presents a set of observations and key questions. Overall, the report shows that, when addressing "optimisation", there is ample scope for clarifying concepts, facts and possibilities and for ensuring that regulatory guidance is sufficiently precise and implementable. The intention is that this report should serve as a basis for discussion within and beyond NEA committees and expert groups.

Partnering for Long-term Management of Radioactive Waste

Evolution and Current Practice in Thirteen Countries

ISBN 978-92-64-08369-1. 132 pages. Price: € 45, US$ 63, £ 40, ¥ 5 800.

National radioactive waste management programmes are in various phases of siting facilities and rely on distinct technical approaches for different categories of waste. In all cases, it is necessary for institutional actors and the potential or actual host community to build a meaningful, workable relationship. Partnership approaches are effective in achieving a balance between the requirements of fair representation and competent participation. With host community support, they also help ensure the desirable combination of a licensable site and management concept as well as a balance between compensation, local control and development opportunities. This report provides up-to-date information on experience with local partnership arrangements in 13 countries. The characteristics, advantages and aims of community partnerships are also described in addition to the concept's evolution over the past decade.

Radioactive Waste Repositories and Host Regions: Envisaging the Future Together

Synthesis of the FSC National Workshop and Community Visit, Bar-le-Duc, France, 7-9 April 2009

ISBN 978-92-64-99128-6. 56 pages. Free: paper or web.

This 7th Forum on Stakeholder Confidence (FSC) workshop focused on the territorial implementation of France's high-level and long-lived intermediate-level waste management programme. Sessions addressed the French historical and legislative context, public information, reversibility, environmental monitoring and the issue of memory. Amongst the participants were representatives of local and regional governments, civil society organisations, universities, waste management agencies, institutional authorities and delegates from 13 countries. This report provides a synthesis of the workshop deliberations.

Regulation and Guidance for the Geological Disposal of Radioactive Waste

A Review of the Literature and Initiatives of the Past Decade

ISBN 978-92-64-99120-0. 40 pages. Free: web only.

Self-sealing of Fractures in Argillaceous Formations in the Context of Geological Disposal of Radioactive Waste

Review and Synthesis

ISBN 978-92-64-99095-1. 312 pages. Free: paper or web.

Disposal of high-level radioactive waste and spent nuclear fuel in engineered facilities, or repositories, located deep underground in suitable geological formations is being developed worldwide as the reference solution to protect humans and the environment both now and in the future. Assessing the long-term safety of geological disposal requires developing a comprehensive understanding of the geological environment. The transport pathways are key to this understanding. Of particular interest are fractures in the host rock, which may be

either naturally occurring or induced, for example, during the construction of engineered portions of a repository. Such fractures could provide pathways for migration of contaminants. In argillaceous (clay) formations, there is evidence that, over time, fractures can become less conductive and eventually hydraulically insignificant. This process is commonly termed "self-sealing". The capacity for self-sealing relates directly to the function of clay host rocks as migration barriers and, consequently, to the safety of deep repositories in those geological settings. This report – conducted under the auspices of the NEA Clay Club – reviews the evidence and mechanisms for self-sealing properties of clays and evaluates their relevance to geological disposal. Results from laboratory tests, field investigations and geological analogues are considered. The evidence shows that, for many types of argillaceous formations, the understanding of self-sealing has progressed to a level that could justify its inclusion in performance assessments for geological repositories.

Towards Greater Harmonisation of Decommissioning Cost Estimates

ISBN 978-92-64-99093-7. 16 pages. Free: paper or web.

Currently, the format, content and practice of cost estimation vary considerably both within and between countries, which makes it very difficult to compare estimates, even for similar types of facilities. The reasons are largely due to different legal requirements in different countries and to historical custom and practice, leading to variations in basic assumptions such as the anticipated decommissioning strategy and end state of the site, and to different approaches to dealing with uncertainties. While attaining harmonisation across national approaches to cost estimation may be difficult to achieve, standardising the way decommissioning cost estimates are structured and reported will give greater transparency to the decommissioning process and will help build regulator and stakeholder confidence in the cost estimates and schedules. This booklet highlights the findings of the NEA Decommissioning Cost Estimation Group (DCEG) which recently studied cost estimation practices in 12 countries.

Towards Transparent, Proportionate and Deliverable Regulation for Geological Disposal

Workshop Proceedings, Tokyo, Japan, 20-22 January 2009

ISBN 978-92-64-06092-0. 196 pages. Price: € 65, US$ 91, £ 58, ¥ 8 400.

As part of its activities, the Regulators' Forum of the NEA Radioactive Waste Management Committee has been examining the regulatory criteria for the long-term performance of geological disposal. In this context, it organised a workshop entitled "Towards Transparent, Proportionate and Deliverable Regulation for Geological Disposal", which served to verify current status and needs. Participants included regulators, implementers, policy makers, R&D specialists and academics. Themes addressed included duties to future generations, timescales for regulation, stepwise decision making, roles of optimisation and best available techniques (BAT), multiple lines of reasoning, safety and performance indicators, recognition of uncertainties and the importance of stakeholder interactions. The workshop highlighted the significant amount of work accomplished over the past decade, but also identified important differences between national regulations even if these are not in contradiction with international guidance. Also highlighted was the importance of R&D carried out on behalf of the regulator. In addition to the contributed papers, these proceedings trace the numerous discussions that formed an integral part of the workshop. They constitute an important and unique documentary basis for researchers and radioactive waste management specialists.

Radiological protection

Occupational Exposures at Nuclear Power Plants

Eighteenth Annual Report of the ISOE Programme, 2008

ISBN 978-92-64-99131-6. 132 pages. Free: paper or web.

The Information System on Occupational Exposure (ISOE) was created by the OECD Nuclear Energy Agency in 1992 to promote and co-ordinate international co-operative undertakings in the area of occupational radiological protection at nuclear power plants. ISOE provides experts in occupational radiological protection with a forum for communication and exchange of experience. At the end of 2008, the ISOE programme included 59 participating utilities in 26 countries (278 operating units and 32 shutdown units), as well as the regulatory authorities of 22 countries. The ISOE database, publications, annual symposia and ISOE Network website (www.isoe-network.net) facilitate the exchange amongst participants of operational experience and lessons learnt in the optimisation of occupational radiological protection. The Eighteenth Annual Report of the ISOE Programme summarises occupational exposure data trends and ISOE achievements made during 2008. Principal developments in ISOE participating countries are also described. ISOE is jointly sponsored by the OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA).

Nuclear law

Nuclear Law Bulletin No. 84

Volume 2009/2

ISSN 0304-341X. 200 pages. Yearly subscription (two issues per year): € 114, US$ 150, £ 91, ¥ 16 500.

Considered to be the standard reference work for both professionals and academics in the field of nuclear law, the *Nuclear Law Bulletin* is a unique international publication providing its subscribers with up-to-date information on all major developments falling within the domain of nuclear law. Published twice a year in both English and French, it covers legislative developments in almost 60 countries around the world as well as reporting on relevant jurisprudence and administrative decisions, international agreements and regulatory activities of international organisations. Feature articles in this issue include "Nuclear New Build – New Nuclear Law?", "Directive Establishing a Community Framework for the Nuclear Safety of Nuclear Installations" and the "Harmonisation of Nuclear Liability in the European Union".

Nuclear science and the Data Bank

Actinide and Fission Product Partitioning and Transmutation

Tenth Information Exchange Meeting, Mito, Japan, 6-10 October 2008

ISBN 978-92-64-99097-5. 454 pages. Free: paper with CD-ROM or web.

For the successful deployment of the advanced fuel cycle, it is important to apply partitioning and transmutation (P&T) technologies to radioactive waste management. In order to provide experts with a forum to present and to discuss the latest developments in partitioning and transmutation, the NEA has organised, since 1990, a series of biennial information exchange meetings on actinide and fission product P&T. These proceedings contain all the technical papers and posters presented at the 10th Information Exchange Meeting, which was held on 6-10 October 2008 in Mito, Japan. The meeting addressed the following technical issues: the impact of P&T on waste management and geological disposal; transmutation fuels and targets; partitioning, waste forms and management; materials, spallation targets and coolants; transmutation physics experiments and nuclear data; and transmutation systems design, performance and safety.

Independent Evaluation of the MYRRHA Project

Report by an International Team of Experts

ISBN 978-92-64-99114-9. 44 pages. Free: paper or web.

The renewed interest in nuclear energy – to a large extent stimulated by concerns about global climate change, high volatility of fossil fuel prices and security of energy supply – has also revived discussions on advanced reactor concepts with the potential to reduce significantly the long-term radioactivity of nuclear waste. One of these concepts is an accelerator-driven system (ADS) which combines a particle accelerator with a subcritical reactor core. The Belgian research centre SCK•CEN at Mol has launched a project aiming to construct an ADS consisting of a high energy proton, linear accelerator combined with a lead-bismuth-cooled, subcritical reactor. The project is called MYRRHA (Multi-purpose Hybrid Research Reactor for High-tech Applications). The Belgian government asked the OECD Nuclear Energy Agency (NEA) to organise an international peer review of the MYRRHA project to provide an independent evaluation as part of the decision-making process. This report presents the findings from the review, which was conducted by a team of seven high-level experts from seven countries, assisted by the NEA Secretariat.

International Nuclear Data Evaluation Co-operation

Complete Collection of Published Reports as of January 2010

Free CD-ROM on request.

The NEA International Nuclear Data Evaluation Co-operation programme brings together evaluation projects being carried out in Japan (JENDL), the United States (ENDF), Europe (JEFF) and non-OECD countries (BROND, CENDL and FENDL). The Nuclear Data Section of the International Atomic Energy Agency (IAEA) sponsors the participation of evaluation projects from non-OECD countries. The programme was established to promote the exchange of information on nuclear data evaluations, measurements, nuclear model calculations, validation and related topics, as well as to provide a framework for co-operative activities among the participating projects. The Co-operation programme assesses needs for nuclear data improvements and addresses those needs by initiating joint evaluation and/or measurement efforts. Expert groups are established to solve specific, common nuclear data problems. Each expert group produces a final report of its findings. This CD-ROM contains the full collection of the expert group reports as of January 2010.

JEFF Reports

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