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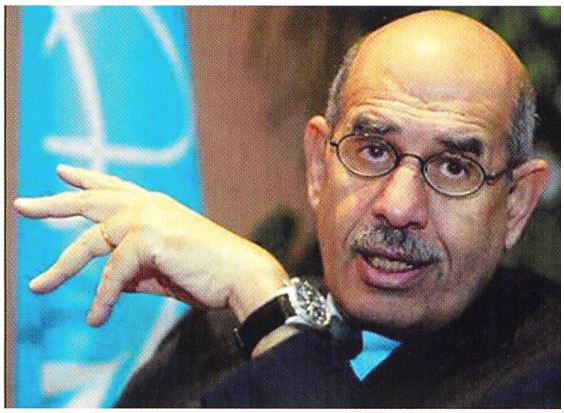
Nuclear Power: A Look at the Future

I saw a headline recently that perhaps captures the spirit of this occasion. It said, «Life Begins at 50.» Some of us I am sure hope that that is true. But as nuclear power celebrates its 50th birthday, its future – while perhaps growing more promising – remains uncertain. I would like to touch on a few aspects of the evolving global scenario for nuclear power – briefly reviewing the current picture, outlining a number of key issues, and discussing what the International Atomic Energy Agency is doing to ensure that nuclear power remains a safe, secure and viable option for supplying energy needs.



Mohamed ElBaradei: «Nuclear power remains a safe, secure and viable option for supplying energy needs.»

■ Mohamed ElBaradei

Past, Present and Future: The Growth of Nuclear Power

Looking Backward

In a 1945 issue of the New York Herald Tribune, the journalist John O'Neill declared that atomic energy would make it possible for the human race to create «an earthly paradise» – an assertion typical of the times in its over-enthusiasm:

«Atomic energy unquestionably will be made extremely cheap – like ‹free air› at the service stations. Our automobiles eventually will have atomic energy units built into them at the factory so that we will never have to refuel them. So will very large airplanes... In a relatively short time we will cease to mine coal.» [1]

Now you can understand why I hesitate to make projections about the future.

Less than 10 years after Mr. O'Neill's prophecy, the reactor at Obninsk was the first to supply energy to the electrical grid. By the early 1970s, nuclear power capacity worldwide was growing at an average rate of 30% per year. Over the next ten years, it continued to secure a steadily larger share of the world electricity market. By 1986, the year of the Chernobyl accident, nuclear power accounted for 16% of global electricity use. From that time forward, it has maintained about the same ratio, growing at the same pace as overall electricity use.

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The Current Mixed Picture: New Construction, Increased Availability, Licence Renewal, and Phase-outs

Of the 442 nuclear plants currently operating, fewer than 10% are located in developing countries. Many industrialized nations generate substantial portions of their electricity from nuclear fission: including: France, at 78%; Belgium, at 55%; Germany, at 28%; Japan, at 25%; the United States, at 20%; and Russia, at 17%. By contrast, for large developing countries such as Brazil, India and China, the percentages are only 3,7%, 3,3% and 2,2%, respectively.

Current expansion and growth prospects for nuclear power are centred in Asia. Of the 27 units under construction worldwide, 16 are located in India, Japan, South Korea and China (including Taiwan, China). Twenty-two of the last 31 reactors to be connected to the grid are also in the Far East and South Asia. By contrast, in Western Europe and North America, nuclear construction has been a frozen playing field – the last plant to be completed being Civaux-2 in France in 1999.

Given this limited amount of new construction, much of the increase in nuclear generating capacity over the past decade has been credited to increased availability – a change tied directly to improvements in global safety performance. To understand the current picture, it is important to understand this trend.

The accident at Chernobyl in 1986 prompted the creation of the World Association of Nuclear Operators (WANO), and revolutionized the IAEA approach to nuclear power plant safety. Both organizations created networks to conduct peer reviews, compare safety practices, and exchange vital operating information to improve safety performance. The IAEA has worked to update its body of safety standards to reflect best industry practices, as well as putting in place legally binding norms in the form of international safety conventions. And a more systematic analysis of risk was used to ensure that changes made were in areas that would bring the greatest safety return.

Although the focus of this international effort was on improving safety, the secondary benefit was a steady increase in nuclear plant availability and productivity. In 1990, nuclear plants on average were generating electricity 71% of the time. As of 2003, that figure stood at 84% – an improvement in productivity equal to adding more than 34 new 1000 megawatt nuclear plants – all at relatively minimal cost.

The result is that existing well-run nuclear power plants have become increasingly valuable assets. Although the initial capital cost of a nuclear plant is high, the operating costs have become relatively low and stable. These improvements to safety and economics have not escaped the notice of investors. They have been a strong factor in decisions to extend the licences of existing plants – for example, in the United States, where 26 nuclear plants have received 20-year licence extensions in the past 5 years, and 50 more have signaled their intention to pursue licence renewal.

Clearly, however, not every country shares the view that improved economics and safety performance warrant a revival of nuclear power. This divergence of opinion is to be expected; each country

Pressures of population growth and the need for economic development that are present in some parts of Asia continues to support nuclear power expansion (Shanghai/photo Siemens).

and region faces a different set of variables when choosing its energy strategy, and energy decisions cannot be made on a «one-size-fits-all» basis.

Consider Europe as an example: as a region, it does not face the dual pressures of population growth and the need for economic development that are present in some parts of Asia. In Finland, a majority of the public continues to support nuclear power expansion, and in Switzerland in May 2003 the electorate, by a two-to-one vote, rejected a phase-out of nuclear power. Yet four other Western European countries – Belgium, Germany, the Netherlands and Sweden – currently have nuclear phase-out policies in place; and a number of countries, including Austria, Denmark and Ireland have stated policies against nuclear power. This opposition generally stems from continuing concerns regarding safety, security and waste disposal, topics to which I will return in a moment.

Projections for the Future: Broad Variation

Overall, the current picture remains mixed, and projections for the future of nuclear power vary widely depending on what assumptions are made. The IAEA's current «low» (or conservative) projection – which assumes that today's nuclear plants will retire on schedule, and assumes no new construction beyond what is already firmly planned – would envision the total amount of nuclear electricity generated dropping off after about 2020. The IAEA «high» projection, which includes additional scenarios for new nuclear plant construction, would envision nuclear power generating 70% more electricity in 2030 than at present, but still tapering off in its global share of electricity, due to even more rapid expansion in other electricity sources.

But a much greater contrast comes if we examine the longer term analyses of the Intergovernmental Panel on Climate Change (IPCC), the International Energy Agency and others. These long term studies, rather than just extending business-as-usual trends, calculate the total energy needed to raise living standards around the world for a growing global population. They also account for the depletion of fossil fuel resources, rely more on what is economically optimal in the long run, and do not assume that the current socio-political situation remains constant. In this context, the median of the IPCC's estimates would envision that, by 2050, nuclear power would quadruple its total output.

Shaping the Future: Critical Issues

In my view, these projections are only valuable to the extent that they highlight what factors will be of crucial influence in shaping the future of nuclear power. I would like to examine a few such issues.

Carbon Emissions and the Growth in Demand

The first issue is the degree to which global attention remains focused on limiting greenhouse gas emissions and reducing the risk of climate change – particularly as the world faces an unprecedented expansion in energy demand in the next 50 years. Much of this surge in demand will occur in nations on the path of economic development. The degree to which fossil fuels are tapped to meet this demand could have a major impact on global air pollution, as well as on the pace of fossil fuel depletion.

Nuclear power emits virtually no greenhouse gases. The complete nuclear power chain, from uranium mining to waste disposal, and including reactor and facility construction, emits only 2–6 grams of carbon per kilowatt-hour. This is about the same as wind and solar power, and two orders of magnitude below coal, oil and even natural gas. Worldwide, if the existing nuclear power plants were shut down and replaced with a mix of non-nuclear sources proportionate to what now exists, the result would be an increase of 600 million tonnes of carbon per year. That is approximately twice the total amount that we estimate will be avoided by the Kyoto Protocol in 2010.

Nuclear should not be viewed as being in competition with «renewable» sources of energy, such as wind, solar and geothermal plants. In fact, nuclear energy is not in competition, per se, with any technology. But as the reduction of carbon emissions becomes a higher priority, both nuclear and these renewable sources could have much larger roles to play. The problem is that no «renewable» source has been demonstrated to have the capacity to provide the «baseload» amounts of power needed to replace large fossil fuel plants. Wind power, for example, may be an excellent choice for sparsely populated rural economies, particularly if they lack modern electrical infrastructure; on the other hand, it seems unlikely that wind power will be able to support the electricity needs of tomorrow's megacities.

In Switzerland in May 2003 the electorate, by a two-to-one vote, rejected a phase-out of nuclear power (photo KKG).

Security of Supply

A second factor is the current emphasis in some regions on ensuring the security of energy supply. The recent Green Paper on Europe's supply security estimated that business-as-usual would increase dependency on imported energy from around 50% today to around 70% in 2030. A similar concern drove nuclear power investment in Europe and North America during the oil crisis of the 1970s. Large uranium resources in a given country or region are not a necessary pre-condition for this security, given the diverse global roster of stable uranium producers, and the small storage space required for a long term fuel supply.

Public Perceptions and Misconceptions: Shaping National Choices

A third factor concerns the influence that public perceptions – including perceptions of risk – have on a country's energy choices. In hindsight, it is not difficult to see why the past five decades of nuclear power did not turn out exactly as predicted. Nuclear energy has long been

marked by feelings of unease and concerns about safety and waste. Nuclear power was dealt a heavy blow by the tragedy of the 1986 Chernobyl accident (a blow from which the reputation of the nuclear industry has never fully recovered). Little distinction has been made, in the media or in public understanding, between the design characteristics of the Chernobyl reactor and the hundreds of other reactors in operation around the world. And despite the array of measures that have been put in place since Chernobyl to offset the possibility of a severe nuclear accident, these risks can never be brought to zero, and they continue to weigh heavily on public perceptions. The environmental superiority of nuclear power as a source of electricity – particularly important in light of recent concerns about greenhouse gases and climate change – has frequently received less attention than the accumulation of spent fuel and radioactive waste.

The failure of the nuclear community – both scientists and technical experts, operators and regulators – to effectively «market» their strengths in comparison with other sources, has contributed to a lack of public understanding regarding the basics of radiation science and the characteristics of nuclear power. For example, in a 2002 Eurobarometer poll, taken in the United Kingdom and the EU15, subjects were asked «Does nuclear power contribute greatly to global warming?» A full 45% of respondents answered «yes», and only 37% correctly answered «no».

These and other misconceptions can be of great influence in shaping public acceptance of nuclear power. How a given nation balances the risk of a nuclear accident against other factors – such as air pollution, dammed rivers, mining accidents, or dependency on foreign fuel supplies – is already a matter of complexity and legitimate debate. It is important for the nuclear community to make every effort to provide comprehensible, accurate information to support that debate, to ensure that the risks and benefits of nuclear technology are clearly and fairly understood.

Performance in Addressing Key Concerns: Safety, Waste Disposal and Security

An extremely important factor – and one over which the nuclear community has some degree of control – is the ongoing performance of the nuclear industry in addressing the key concerns I mentioned earlier related to nuclear power: namely, safety, waste disposal and, more recently, security.

Nuclear Safety

As I have already mentioned, the development of strong international nuclear safety networks over the past two decades has paid off, and I feel confident in saying that nuclear safety has dramatically improved. But we should not rest on our laurels. There are still gaps: in some cases, existing facilities with older design features will require a continuation of upgrades and compensatory measures to ensure acceptable levels of safety into the future. We are also focused on identifying problems with similar root causes, to prevent recurring events at nuclear facilities: that is, ensuring that lessons learned at one nuclear plant are effectively incorporated into the operational practices of all other relevant nuclear facilities.

Moreover, as nuclear power technology continues to spread and more countries develop indigenous plant designs, the resultant diversification also highlights the importance of several safety considerations: ensuing quality; managing and sharing knowledge; using common, internationally accepted safety standards; promoting cooperation and sharing of experience among regulatory authorities; and adapting the practices of international vendors and contractors to the diverse cultures of countries with new nuclear programmes.

The IAEA continues to work towards the development of sound collaborative approaches for dealing with these issues. Continued strong safety performance is essential if nuclear power is to remain a viable energy option, and should remain a global priority.

Management and Disposal of Spent Nuclear Fuel

In terms of actual implementation, the management and disposal of spent nuclear fuel remains a challenge for the nuclear power industry. When the actual amount of spent nuclear fuel produced globally every year – 12 000 tonnes – is contrasted with the 25 billion tonnes of carbon waste released directly into the atmosphere every year from fossil fuels, the amount of nuclear waste seems relatively small. In addition, most technological hurdles to spent fuel disposal or reprocessing have already been solved. But public opinion will likely remain skeptical – and nuclear waste disposal will likely remain controversial – until the first geological repositories are operational and the disposal technologies fully demonstrated.

In this regard, the greatest progress on deep geological disposal has been made in Finland, Sweden and the USA. Finland´s Government and Parliament have approved a decision «in principle» to build a final repository for spent fuel near Olkiluoto. Construction should start in 2011 and operation in 2020. Sweden has begun detailed geological investigations at two candidate sites, and hopes to make a final site proposal by about 2007. In the US, the President and Congress in 2002 approved proceeding with the disposal site at Yucca Mountain, where operations are planned to begin in 2010.

The IAEA has been working hard to help its Member States develop waste management and disposal strategies, and to facilitate international cooperation in waste disposal research and demonstration projects. In that regard, I have begun to encourage multinational approaches to spent fuel management and disposal. More than 50 countries have spent nuclear fuel, including fuel from research reactors, stored in temporary sites, awaiting disposal or reprocessing. Not all countries have the right geology to store waste underground and, for many countries with small nuclear programmes, the costs of such a facility would be prohibitive. I am encouraged that the Russian Federation is considering one such collective disposal initiative.

Nuclear Security

Nuclear security has also gained importance in recent years. The September 2001 terrorist attacks in the United States naturally led to the re-evaluation of security in every industrial sector, including nuclear power. Both national and international nuclear security activities have greatly expanded in scope and volume; in the past two years, we in the IAEA have worked on every continent to help countries better control their nuclear material and radiological sources, protect their nuclear facilities and strengthen border controls. Here, too, the international community is making good progress; while much remains to be done, nuclear installations around the world have strengthened security forces, added protective barriers, and taken other measures commensurate with current security risks and vulnerabilities.

Technological and Policy Innovation

Another factor to be considered is innovation – encouraging the development of new reactor and fuel cycle technologies. To be successful, these innovative technologies should address concerns related to nuclear safety, proliferation and waste generation – and must be able to generate electricity at competitive prices. From a technical standpoint, this implies a greater reliance on passive safety features, enhanced control of nuclear materials through new fuel configurations, and design features that allow reduced construction times and lower operating costs. And the innovation must be more than purely technical: policy approaches must be put in place that enable reliable construction schedules, licensing review procedures, and other factors affecting cost and consumer confidence.

In view of changing market requirements, we are giving particular attention to small and medium sized reactors, which allow a more incremental investment, provide a better match to grid capacity in developing countries, and are more easily adapted to a broad range of industrial settings and applications such as district heating, seawater desalination, or the manufacture of chemical fuels. Nearly 20 IAEA Member States are currently involved in the development of innovative reactor and fuel cycle designs. The Agency has been promoting innovation through its International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), and is also working with other national and international innovation projects.

Growing Interest in «Hydrogen Economy»

A final factor that could have a large influence on the future of nuclear power concerns its potential to indirectly supply energy for transportation. Despite the 1945 predictions of Mr. O'Neill and others, nuclear-fueled transport has never become a reality except in terms of nuclear-powered military submarines and surface ships. However, with growing concerns over the greenhouse gases emitted by fossil-fuel-powered vehicles, this could change.

Recent years have witnessed a surge of interest – and widespread R&D efforts – related to the use of hydrogen fuel cells in transportation and the potential for a so-called «hydrogen economy». Like electricity, hydrogen as a fuel is environmentally benign; however, like electricity, hydrogen must be produced – pure hydrogen does not exist in nature to be mined or refined. Both of the primary hydrogen production processes under consideration – electrolysis and steam reforming of methane – are energy intensive and require the consumption of some other form of fuel.

This creates quandaries. For example, hydrogen could be produced using coal-fired electricity, but the resulting carbon emissions would offset any environmental benefits achieved through the subsequent hydrogen use. Similarly, steam reforming of methane is more energy efficient than electrolysis, and could be achieved using nuclear energy or any other high heat source – but the process itself would release carbon dioxide.

To explore alternatives, major hydrogen research initiatives are currently underway in Japan, China, Europe and the United States. These initiatives are also exploring innovative nuclear designs to produce hydrogen – such as the use of thermochemical reactions under high heat – which could achieve both greater energy efficiency and carbon reductions for the transportation sector.

Conclusion

While it is difficult to predict with any confidence what the next fifty years holds for nuclear power, the factors that will shape the future of nuclear power are relatively evident, and we should take action to address those factors, to enhance the prospects that nuclear energy remains a viable source of safe, secure and environmentally benign energy.

[1] Quoted in The Atomic Age Opens, Pocket Books, New York, August 1945.