CONTROVERSIAL REVERSAL OF NUCLEAR OPTION

by

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Received on October 28, 2002; accepted on November 29, 2002

Nuclear option is in a unique position to restore its original role of the main source of energy with an increased attention paid to the security of electricity supply as well as regulatory changes affecting fossil fuels, particularly with due introduction of climate change prevention measures. Recent developments indicate the advantages of nuclear option over other possible options in terms of sustainable development. However, a large number of controversial issues on nuclear energy make its reversal less clear. These are discussed with particular attention paid to recent developments worldwide, including the World Summit on Sustainable Development held in September 2002 in Johannesburg, South Africa.

Key words: nuclear option, security of supply, sustainable development, climate change

INTRODUCTION

Our society is dependent on energy for industrial production and the abolition of tiring physical labor, as well as for mobility and the use of countless computer and communication devices. World energy demand will continue to grow as population increases and countries undergo industrial development and economic expansion. To meet these increasing demands, and to improve the standard of living for future generations, large increases in electricity generation will be necessary. Such increases must be achieved in a sustainable way that has the lowest possible environmental impact.

Nuclear power accounts for about 17% of the world's electricity production, generated from some 438 reactors with an installed capacity of 353 gigawatts in 31 countries around the world [1]. The US hosts a quarter of the world's reactors. The European Union obtains about 35% of its electricity from nuclear power, which is the largest share of all energy sources in the region. India and China, two developing nations that represent almost half of the world's population, have substantial programmes to increase electricity generation from nuclear. Nuclear power plants provide important benefits that are not found with other energy options. These plants have proven to be highly reliable in all weather conditions, cost-effective in operation, and act as crucial anchors to the national electric grids.

Any future decline in nuclear's contribution to energy supply in Europe (Fig. 1) will have serious implications for the world's economy and environment [2]. Nuclear is a strategically important energy supply because it offsets dependence on oil and gas, which are politically sensitive. The earth's fossil resources are finite and should be preserved as much as possible. Unlike nuclear, they have important industrial uses other than power generation. Nuclear power also makes a valuable contribution to the avoidance of greenhouse gas emissions. This is, therefore, an appropriate moment to reassert the contribution that nuclear makes to meeting the need for abundant and clean electricity.

Nuclear plants do not emit pollutants such as nitrogen oxides, sulfur oxides, mercury, or particulates that affect human health. Nor do nuclear plants emit carbon dioxide. However, nuclear may not be an ideal energy option in every part of the world, as certain regions have no power transmission network. In addition, investment in nuclear may not

Review paper
UDC: 620.9:621.039
BIBLID: 1451-3994, *17* (2002), 1–2, pp. 50–63

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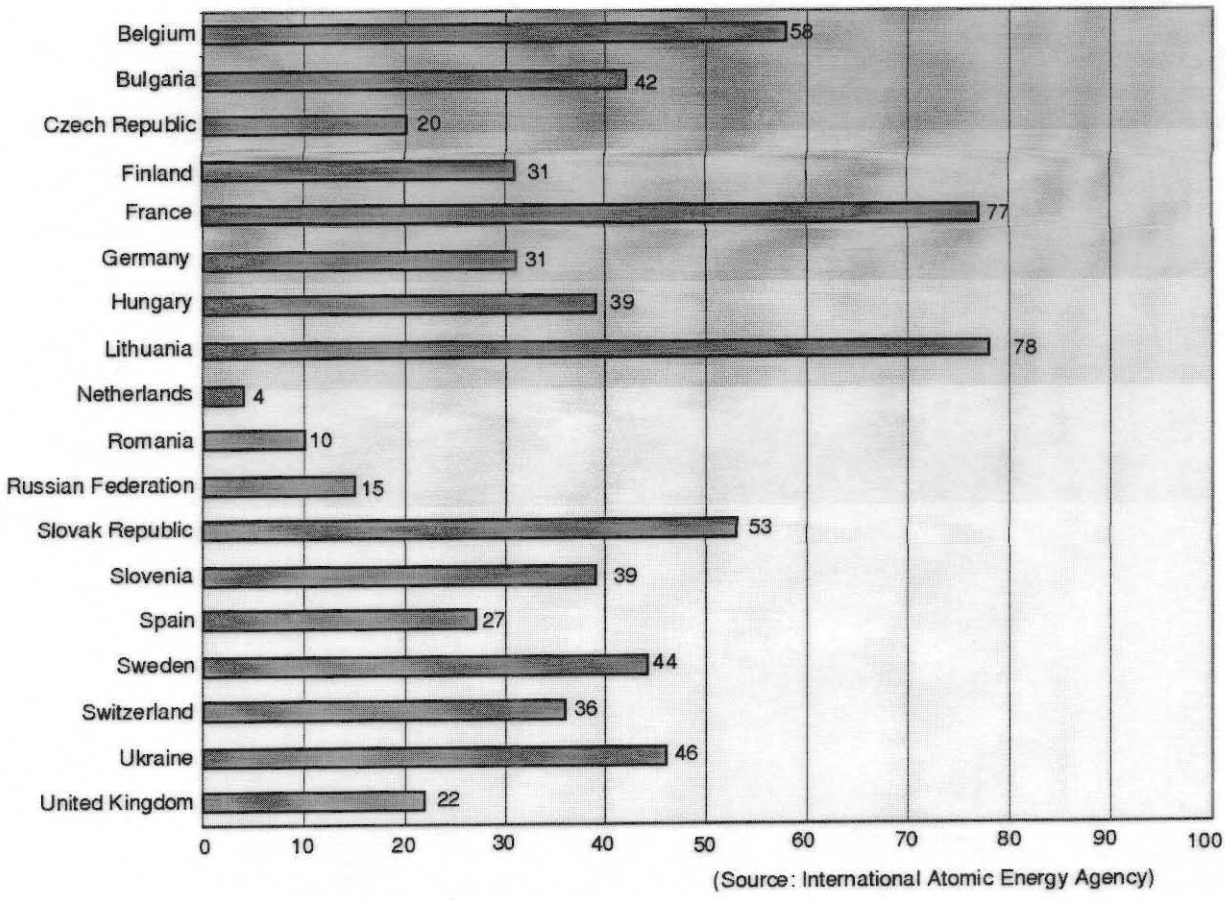

Figure 1. Nuclear share % of total electricity generated in 2001

be justified in areas where electricity demand is low. Nevertheless, like all sources of energy, nuclear power has issues with which it must deal. Utilities must make sure that high construction costs characteristic of many nuclear plants completed in the late 1980's and early 1990's are not repeated. Countries must successfully resolve the problem of nuclear waste. Some 51% of the EU's population thinks that nuclear power should remain an option for electricity production in the EU if all waste is managed safely [3]. Even some of the most outspoken opponents would be willing to consider nuclear sustainable if it could be proved that a solution had been found for the waste problem.

Nuclear technology is not just about producing electricity. Nuclear technologies have applications in agriculture, increasing crop yields, and contribute to improved food safety. Medicine relies heavily on nuclear technologies for diagnosis and treatment. Some countries, such as Morocco, Egypt and Tunisia, are considering the use of nuclear power to drive water desalination plants and ensure adequate supplies of fresh water.

NUCLEAR TECHNOLOGY DEVELOPMENT

Generation IV of nuclear energy systems

Most operating nuclear power plants are based on the experience gained from the first generation of nuclear plants that were built and operated in late 1950's and early 1960's. These demonstrations of the practicality of nuclear power enabled second generation plants to be built all over the world, including more than 100 in the United States [4]. The lessons learned from the second generation plants led directly to the development and deployment of the third generation (*i. e.*, advanced light water) nuclear plants beginning in 1990's. The next generation, Generation IV of nuclear energy systems, would take the next step in the evolution of nuclear power plant design. Finding new approaches to make nuclear power more cost-effective while further enhancing safety and proliferation-resistance will enable nuclear energy to fulfill the role envisioned in the early days of the development of atomic fission.

The Generation IV technology goals reflect the need for future nuclear energy systems to build upon the world's experience with nuclear technology and develop systems that can be fully competitive with any other form of energy production. These goals represent a new way of thinking in the nuclear community, recognition that nuclear energy must fully support all economic, environmental, and societal ambitions to meet its initial promise as a widely used source of energy, providing benefit to all nations.

The pebble-bed reactor

Perhaps the most remarkable new development is the prospect of building new nuclear plants, which would have been unthinkable without deregulation. The new nuclear power plants will include new reactor types, generation IV or even pebble-bed reactors. Based upon a successful development of the 110 MW prototype pebble-bed reactor in South Africa, approval is also sought in the U. S., where construction could begin in 2006, with new plants appearing about 2007 as the new reactors would most likely be located at current nuclear plant sites.

The pebble-bed reactor is helium-cooled, in contrast to the light-water reactor designs operating now worldwide. The pebble-bed modular reactor is smaller, simpler and safer than any other reactor plant. Such a plant has fewer moving parts and requires a smaller crew, making its operation less prone to problems as there are no pumps. Because the fuel is encased in a ceramic ball – or pebble – it can be stored much more safely. The pebble bed's simpler, modular design and smaller size would also cut construction time – to two years from the 10 years it took in the 1980s – and cost. According to the estimates in Ref. [1], a 110 MW pebble-bed plant would cost 125 million $, 1136 $/kW.

NUCLEAR SAFETY ISSUES

Nuclear power has long suffered under a cloud generated by the 1979 accident at Three Mile Island, where a nuclear reactor overheated. Since then that facility was changed a lot, and, as a result, the Three Mile Island turned out to be one of the best examples for improving nuclear safety worldwide. Still, there remains the legacy of Chernobyl, the 1986 disaster that spewed radioactive waste over a swath of the former Soviet Union and Europe. Nevertheless, a global network of technical co-operation has helped the nuclear industry to attain an excellent safety record. To fears that such a catastrophe could be repeated, nuclear industry counters that its power source produces no air pollution and doesn't contribute to global warming.

Nuclear safety is of fundamental importance world-wide, but concerns about it should not be stimulated without foundation, nor used in a purely political context to prevent or delay the reception of countries wishing to join the European Union. The current principles concerning the reception issue date back to a time when the 1986 Chernobyl accident was still fresh in people's minds. New guidelines are needed to take account of the considerable progress made in improving the safety of Russian-design reactors, as a great deal of Western assistance has gone into achieving these improvements [3]. Discussions about the use of nuclear power in the states candidates for membership should focus primarily on the current status of safety at the plants concerned. At the same time, policy-makers should fully recognise the right of sovereign nations to determine their own energy options.

The transport of radioactive materials is carried out under strict regulatory controls, and an excellent safety record has been maintained in this highly specialised field. There are more than 10 million transports of radioactive material around the world each year. Most involve packages containing radioisotopes used in medicine, industry, agriculture or scientific research. In the past 40 years, about 30 000 tonnes of spent nuclear fuel have been transported safely around the world, across distances totalling more than 25 million kilometres by road, rail and sea [5]. The highest possible safety standards, covering all means of transport, are enforced in accordance with internationally agreed requirements. Since the start of the nuclear industrial era some 40 years ago, there has never been a transport accident resulting in the injury or death of an individual as a result of the radioactive nature of the cargo. Nor has there ever been any impact on public health or the environment. Regulations applied to the transport of radioactive materials are designed to ensure that the risks to public health and the environment are negligible. The prime objective is to protect people, property and the environment against direct and indirect effects of radiation during transportation.

ECONOMIC ISSUES

Technological progress and improved operations continue to lower the cost of nuclear electricity generation. Existing nuclear power stations are very cheap to run. Once the capital costs have been incurred, there are enormous economic advantages in keeping them going for their full lifespan. The decision to prematurely shut down the existing stations faced in Sweden, Belgium and in Germany,

is not only a waste of an important capital resource, but it requires a switch to alternative power generation that may produce power at two to three times higher costs, and at the same time is likely to have a worse safety record.

According to the EU's own statistics, existing reactor units produce power at a cost of between 1.6 and 1.9 cents per kWh, compared with 2.5-2.7 cents per kWh for plants that burn natural gas, Table 1, [5–11]. Regarding nuclear new-build, independent research indicates that the proposed new reactor unit in Finland would operate at the cost of 12.8 Finnish pennies per kWh, compared with 14.3 for coal and 15.5 for gas [12]. In Hungary, investment costs for lifetime extension of their Paks nuclear power plant up to 50 years have shown advantage over a new combined cycle gas plant if real electricity price levels remain above 5.85 HUF (2.04 US cents) per kWh [12].

Table 1. Cost comparison of nuclear, gas and wind power in the EU

Nuclear plants (fully amortised)	1.2-1.6	€ cents per kWh
New nuclear plants	2.4-3.0	€ cents per kWh
Gas (low fuel price level)	2.5-2.7	€ cents per kWh
Wind turbine generator	4.8	€ cents per kWh

PUBLIC PERCEPTIONS OF NUCLEAR OPTION

Public perceptions of nuclear option are varying from one country to another. There is a strong correlation between public concerns and a lack of information on radioactive waste. Concerns are the highest in the states where people are not sufficiently well-informed. According to opinion polls, most EU citizens say they are not well informed and want to know more [13]. Most of them believe that nuclear power should remain an option, provided all radioactive waste is safely managed.

However, nuclear energy is not given political priority it deserves. Instead, it is discussed on high morality grounds and on the basis of often unjustified emotions. The general public and particularly politicians of many countries are set against nuclear power (both the existing and new reactors), and some even use legal mechanisms to ban any activity in that respect. Since nuclear power has thus been a political issue for too long, now a mature and a more realistic approach is needed to the nuclear energy in terms of security of supply, as well as of the market competitiveness and sustainable development [14].

Effective public information work is essential to any consultation process. This is a responsibility of governments, national waste management agencies, the European Commission and waste producers. Communication with the public should be objective and transparent in order to increase public confidence and possible support. Discussions during any consultation process should be based on facts, rather than emotion. The process itself may take a very long time. Ideally, communities near potential disposal sites should be consulted at an early stage and often.

RADIOACTIVE WASTE DISPOSAL ISSUE

Radioactive waste comes from nuclear electricity generation and the application of nuclear technology in the medical, industrial and research fields. Most radioactive waste (90%) is low in radioactivity. It is made up of materials such as paper, rags, tools, clothing and filters. This waste is disposed of in facilities built for the purpose on or near the surface. Heavy metals never lose their toxicity, whereas radioactivity reduces in time. Spent nuclear fuel will take at least 10 000 years to lose its radioactivity. The time period is 1000 years for high-level waste left over after nuclear fuel reprocessing.

Spent nuclear fuel and highly radioactive waste left over after the fuel is reprocessed. Quantities, although comparatively small, have been growing for over 40 years and continue to grow. So far in Europe, only Finland has taken a firm decision on a disposal site [15]. Sweden is also making good progress, and in the U. S., the Yucca Mountain repository project has been given the go-ahead. There are no technical reasons for delaying radwaste disposal. Delays in decision-making could mean leaving a legacy for the next generation, and therefore the present generation should leave behind not only the waste, but also the responsibility for future decision-making and disposal.

In the past, there were technical reasons for delays, since allowing the material to "cool" makes disposal easier. At present, spent nuclear fuel and all types of radioactive waste are being safely managed and stored under strict regulatory control. For waste handling and disposal special techniques had to be developed. The results of geological research had to be produced. Interim storage is not a problem, as the volumes involved are comparatively small. All forms of radioactive waste are safely managed and stored. Waste volumes have been substantially reduced through use of advanced techniques.

Political support for disposal projects starts to decline when public opposition is expected. This reinforces the public's initial suspicions and resistance, making politicians less likely to take decisions. Politicians are generally reluctant to take up this issue, because of its potentially negative conse-

quences at election time. Radwaste management is not a technical or financial problem. The real challenges involve public acceptance and political decision-making. As the obstacles in this area are political – not technical or financial, political will is needed to bring about the construction of deep underground repositories for the final storage of highly radioactive materials. However, there is still the need to press ahead with final disposal solutions for high-level radioactive waste and spent nuclear fuel.

Each year, the EU produces about 2 billion tonnes of all types of waste (about four tonnes per person), of which around 35 million tonnes is classified as hazardous waste (80 kilos per person) [2]. There are around 55 000 sites contaminated by waste unrelated to the nuclear sector, which is a threat to public health and groundwater quality. On the other hand, the EU produces about 50 000 cubic metres of radioactive waste per year (0.00013 m^3 per person), which is equivalent to 0.13 litres per person or 9.75 litres over one person's whole (75-year) lifetime. Less than 1% of this is high-level radioactive waste, even when in a form ready for disposal. The EU has so far carried out the disposal of only 2 million tonnes of radioactive waste (low- and medium level). The sites used for this are closely regulated and monitored. Among the largest sites are Drigg, in the UK, the Centre de la Manche and the Centre de l'Aube, both in France.

European Institutions are proposing a draft Directive that would require EU member states to set clear timetables for the management of radioactive waste in general and, in particular, the deep burial of spent nuclear fuel and the highly radioactive waste left over after reprocessing of spent fuel. Environmental Impact Assessments (EIA) are required for radwaste disposal facilities. They are viewed as an effective way to fully involve the public in the decision-making process, and represent an opportunity to establish a full and open dialogue.

For the disposal of spent fuel and high-level waste, there is a broad international consensus among experts, favouring the concept of deep geological disposal, using both natural and man-made barriers. All the necessary technologies have been tried and tested. Research is continuing to further refine data, models and concepts. The European Commission has stated that high-level waste could almost certainly be safely disposed of today – if sites were available. However, most people are not willing to accept another country's radioactive waste, and each country should be self-sufficient and capable of disposing of its own radioactive wastes. No country can be forced to take another country's waste, but voluntary regional collaboration is a future option that might produce environmental and economic advantages.

Thus, those that generate radioactive waste should dispose of it in a safe and appropriate manner. This is an issue that must be addressed by this generation, not the next. The EU member states press ahead with plans to develop and operate repositories for spent nuclear fuel and high-level waste. The public is better informed, and governments should set clear, long-term objectives aimed at resolving this important environmental issue. To make spent fuel and high-level waste retrievable, a future technology will enable making the material harmless. Retrievability is seen as important for gaining public acceptance. However, retrievability carries with it an undue risk of accidental recovery or release. Another school of thought is that no disposal system can ever make anything completely irretrievable.

Decommissioning is a major source of radioactive waste, as some parts of plants undergoing dismantling can be highly radioactive. Nuclear plant decommissioning is no longer just an area of research, but has reached industrial maturity. The next ten years will see a large increase in the number of nuclear facilities being decommissioned in the EU, as reactor units reach retirement age, after an average of 40 years in operation. This is also an important issue in the context of EU enlargement.

Nuclear plant operators make special financial provisions for decommissioning and radioactive waste management. Within power generation sector as a whole, nuclear energy industry is unique in this respect. This ensures that adequate finance is available when the time comes to build waste disposal facilities and decommission plants. In some cases, these provisions are accumulated by factoring them into the cost of each nuclear kilowatt-hour, Figs. 2 and 3 [16].

Techniques are already in use for the safe decommissioning of nuclear facilities and the restoration of nuclear sites. Actuel decommissioning costs are turning out to be lower than originally predicted, thanks to technological advances and to the accumulation and sharing of technical know-how and data. European nuclear industry includes companies that are world leaders in the huge global market for decommissioning of nuclear plant and site restoration.

Besides proven technologies and strict regulations that exist for managing radioactive wastes in ways that are safe, economical and environmentally sound, considerable experience exists with these technologies in many countries. Radioactive waste can be stored safely in a monitored and retrievable form for a very long time. Universally, the overriding objective is to manage the waste in such a way as to protect human health and the environment and to limit any burden on future generations. Waste is processed into a solid form and is encased in special

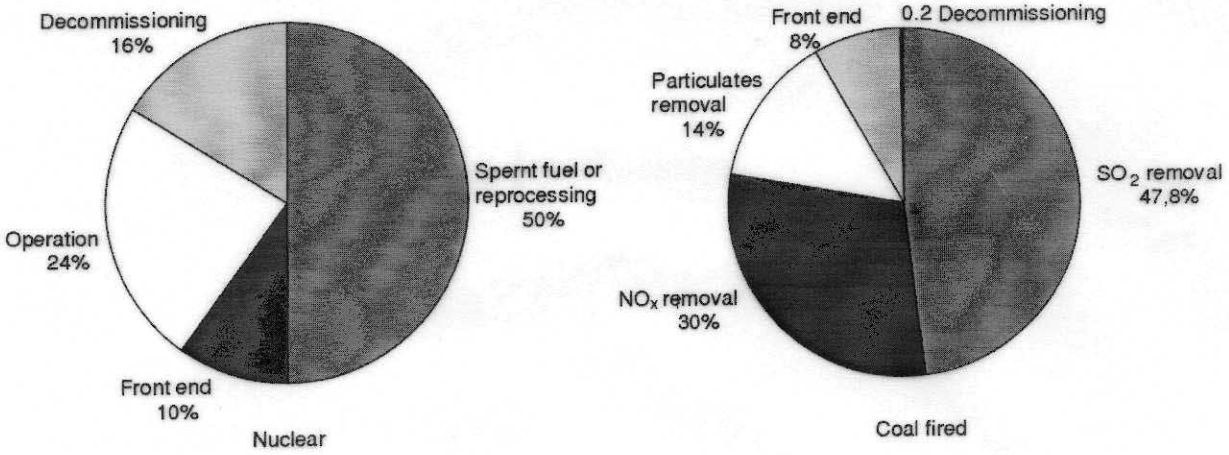

Figure 2. Waste management cost constituents for nuclear *vs.* coal fired power plants

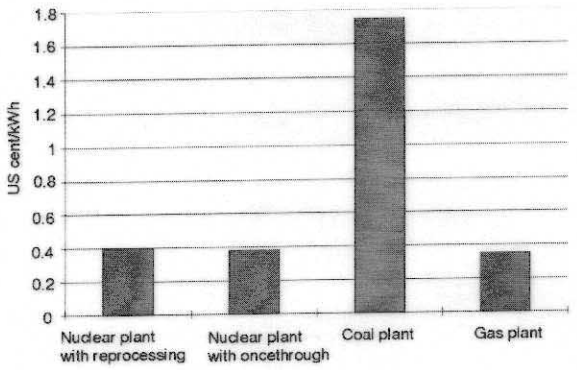

Figure 3. Waste management cost comparison for nuclear *vs.* fossil fired power plants

containers before being placed in a facility on or near the surface or under ground. Natural and engineered barriers are used to isolate the waste from the biosphere. Around the world there are many disposal concepts for spent nuclear fuel and for the high-level radioactive waste left over after the reprocessing of spent nuclear fuel.

So far, no great urgency has been necessary because of the safety of existing facilities that store this material on an interim basis. Disposal deep under ground is emerging internationally as a preferred option. The basic technology and financing mechanisms are already in place for the construction of deep underground repositories. Building up political consensus and public acceptance should now be top priority, in order to achieve further progress in this area. Significant progress is already being made in Finland, Sweden and the US. A majority of Europeans believe the present generation should take responsibility for its radioactive waste, according to the results of an EU-wide poll published in 2002 by the European Commission [15]. The present generation has derived enormous benefits from nuclear technology, and it is its duty to permanently resolve this important environmental issue.

When nuclear fuel is removed from a reactor after being used, it can follow one of two distinct routes. Government policy may dictate that it should be disposed of. In this case, it is classified as waste. Alternatively, the power company involved may be in a position to have the spent fuel reprocessed. In this case, it is considered a valuable energy resource destined for recycling. Reprocessing carried out by two major companies, BNFL in the UK and Cogema in France, results in the recovery of 97% of the reusable material inside spent fuel. This is made up of uranium and plutonium, and both can be used in the production of mixed oxide (MOX) fuel. The remaining 3% is highly radioactive waste which is immobilised in glass – a process called vitrification – and encased in special containers for long-term storage in facilities built for the purpose. At a later stage, vitrified waste can be disposed of in deep underground repositories, in the same way as spent fuel that has not been reprocessed.

SECURITY OF SUPPLY

Nuclear energy enables countries to reduce their reliance on imported fossil fuels and electricity imports, increase their energy independence and strengthen security of energy supply. With greater reliance on nuclear energy, countries are less likely to be seriously affected by fossil fuel shortages and sudden rises of fossil fuel prices. Europe, for example, is heavily dependent on the Middle East and Russia for its oil and gas supplies, and political instability in certain regions could lead to supply shortages and price rises. On the other hand, uranium used in nuclear fuel is available from various countries with a long history of political stability, including Australia and Canada. This has a stabilis-

ing effect on uranium prices and supply. Any rise in uranium prices would have only a minor impact on the cost of a nuclear kilowatt-hour, as fuel makes up a comparatively small part of the total cost of producing nuclear electricity. Power plants that burn fossil fuels are more fuel-intensive, and therefore both producers and consumers face a much greater risk of increased costs due to higher fuel prices [17].

Federal Republic of Yugoslavia is dependent on its external energy supplies. Yugoslavia currently imports some 60-70% of its requirements of oil and gas, but also imports high quality coal and even electricity. If current trends persist, the dependence on oil and gas import will rise to about 80% and more in 2010 [12]. Therefore, longer-term projections should include nuclear option as well, since coal deposits in Kosovo and Metokhia Province may not be at its disposal for generating electricity. However, in Yugoslavia, a federal law banning the use of nuclear energy is still in force, which was imposed due to public opposition in late 1980s when the local situation in electricity generation was different.

Present energy policy is required to ensure a balance between security of supply, competitiveness and environmental requirements. Recent changes involved by deregulation and liberalization of electricity and natural gas markets even strengthen such a policy. Dependence on external energy sources is unavoidable, but relying on imports for a large percentage of total energy supply carries risks that have to be managed since a large proportion of both oil and gas reserves are found in politically unstable regions. Electricity is a product that cannot be stored and this restricts the extent to which there can be a real free market for electricity. Therefore, relying on imports of electricity to a large extent may prove very inadequate. This is particularly so in the region of South-Eastern Europe, despite very good prospects for development of the regional electricity market there.

Electrical energy is a fundamental prerequisite for a civilized life and an essential commodity. The use of nuclear energy has no risk associated with external dependence because there are abundant quantities of uranium available worldwide from many different sources. Uranium ore in known reserves, amounting to 15.4 million tonnes, is sufficient for 255 years at current rates of consumption [13]. In addition, large amounts of uranium are stockpiled at various stages of the nuclear fuel cycle. The inherent mitigation of supply risk associated with the use of uranium should act, among other factors, as an incentive to further use of nuclear energy. In addition, nuclear is physically a highly compact energy source, and there are already very large stocks of fuel assemblies and fuel-making materials available, especially when these are measured in terms of power generating capacity per year at current production rates. It is, therefore, very important for any country to recognize such strategic aspect of nuclear energy when addressing the issue of security of power supply.

NUCLEAR AT THE WORLD SUMMIT ON SUSTAINABLE DEVELOPMENT

A very important contribution is made by nuclear in terms of the avoidance of greenhouse gas emissions. Electricity from nuclear power does not produce greenhouse gases, and by using nuclear instead of burning fossil fuels for electricity generation avoids emission of CO_2 from alternative fossil generation. Nuclear generated electricity makes it possible to avoid annual release of some 1.8 billion tonnes of CO_2 world-wide. In Europe alone, climate-friendly nuclear electricity saves the emission of about 500 million tonnes of CO_2 a year. To make an equivalent saving by reducing car use, the amount of motoring done in the EU would have to drop by 75%. CO_2 emissions can be further avoided by building new power reactors, upgrading existing nuclear plants to increase output and by extending plant operating lifetimes.

Nuclear energy projects are excluded from the Clean Development Mechanism (CDM), one of the measures under the Kyoto Protocol designed to promote "clean air" energy projects in the developing world. The mechanism would allow industrialized nations to gain special "credits" for pursuing projects that would control, limit or avoid greenhouse gas emissions and contribute to sustainable development in less developed countries.

Energy was one of the most controversial issues at the World Summit on Sustainable Development, held in Johannesburg in September 2002. The aim of the World Summit was to review progress since the first World Summit on sustainability held in Rio in 1992, and to identify ways in which sustainable development could progress in all nations. The objective was to produce a Plan of Implementation which would reinvigorate commitments to the implementation of the famous Agenda 2 [17].

After much debate, efforts to agree on a specific target for the growth of renewable energy worldwide failed at the Summit. The debate over whether to prescribe a target or not delayed final agreement on the overall plan of implementation, which calls for countries to substantially increase the use of renewable energy and to phase out the subsidies for non-sustainable energy sources "where appropriate". Such an agreement was blocked largely by national protectionism, self-interest and short-term thinking. Specifically, the question of

adopting a global renewable energy target, excluding major hydropower and traditional biomass, remained one of the most controversial issues.

At the closing stages of the World Summit on Sustainable Development in Johannesburg, world leaders promised to improve access to reliable and affordable energy services to the poor and to halve the proportion of people living in poverty by 2015 [4]. All forms of energy, including nuclear, will be needed in the ongoing quest for sustainable development. Specific options aimed at long-term solutions should not be excluded because of short-term political pressures. The coal based synthetic fuel (synfuel) industry, which only three years ago was considered a novelty, is poised to dramatically rump up its output in coming years.

As concern about the environment generates interest in ultra-clean energy plants, fuel cell power plants can respond to the challenge. Fuel cells convert hydrocarbon fuels to electricity at efficiencies exceeding conventional heat engine technologies while generating extremely low emissions [18]. Emissions of SO_x and NO_x are expected to be well below the current and anticipated future standards. Nitrogen oxides, a byproduct of combustion, will be extremely low in this type of power plant because power is produced electrochemically rather than by combustion. Due to its higher efficiencies, a fuel cell power plant also produces less carbon dioxide. Fuel cells, in combination with coal gasification, are therefore an efficient and environmentally acceptable means of using the abundant coal reserves around the world.

The potential for expanding large-scale hydro is extremely limited, and nuclear fusion is still a long way off. Wind farms and solar can play a supporting role, but the amount of power these sources can provide is extremely low compared to nuclear [19]. They are also dependent on changeable factors, such as wind strength and sunshine. This makes them unsuitable for baseload generation, the power needed round-the-clock, day and night. Nuclear power plants, meanwhile, are an excellent source of baseload power. Wind and solar also have their environmental and economic disadvantages. If all EU's nuclear plants were replaced by wind turbines, they would cover an area of 32 000 square kilometres. Installing solar cells to replace a nuclear power plant (cost 2.56 billion €) would require an investment of around 92 billion € [19]. The solar cells involved would cover 150 square kilometres.

Many environmental and industry groups were disappointed when the Summit failed to agree on global targets for the growth of renewable energy. A global growth target would be helpful to accelerate the introduction of high-efficiency cogeneration and decentralized renewable energy technologies, as they deliver a range of benefits, including environmental improvement, greater security of fuel supply and (in some cases) lower-cost energy supply. However, it is equally probable that nuclear power shares the same goals of clean and low-cost electricity supply [16]. Therefore, it is better to set targets for greenhouse gas emission reductions, which already exist through the Kyoto Protocol. The challenge is to achieve the target at least possible cost through the use of market mechanisms such as emission trading.

The Summit has shown that developing countries need to be in a position to choose what cleaner technologies would best meet their energy access needs effectively. Clearly, all energy options need to be open and accepted as the fundamental policies of sustainable energy development. For many countries, nuclear energy will play an important part in achieving this objective, while meeting the highest environmental targets. The Plan of Action, agreed in Johannesburg, acknowledged that some countries chose to use advanced energy technologies, such as nuclear power, to meet sustainable development goals.

ACTUAL NUCLEAR SCENE WORLDWIDE

Nuclear reversal in the USA

Power generation in the USA relies heavily on coal with 56.3 per cent of the power or 1807 billion kWh generated using coal in 1998. As total U. S. coal consumption is increasing from 1043 to 1279 million tonnes a year between 1998 and 2020, the average annual increase is projected to be 0.9 per cent [1]. About 90 percent of the coal consumed in the US is used for power generation. In the next 20 years, coal is expected to remain the primary fuel for power generation, although its share of total generation is expected to decline between 1998 and 2020 as natural gas increases its share. However, the building boom has entered the "bust" phase of the power industry commodity cycle, yet 2002 will set new records in plant additions, in spite of cutbacks and deferrals. The current best estimate is that about 290 000 MW of gas-fired power stations will have to be added between 1998 and 2007. About 110 000 MW are under construction of which 69 000 MW are expected to come on line by the end of the year while 41 000 MW were added in 2002.

The downward trend in the boom of new power plants continued throughout the second quarter of 2002. Developers of power plants are currently pursuing an aggregate of 335 GW of new gas-fired capacity over the 1998 to 2007 time frame, down from the 348 GW actively being developed during the previous quarter [3]. Although the years

2002 and 2003 are each expected to set records for new capacity as the amount of capacity under construction currently exceeds 110 GW, the aggregated capacity currently under development shows that 294 GW will be built over the time frame. The on-going deferrals and cancellations of gas-fired projects has trimmed the expected surge of capacity under construction.

On the other side, nuclear industry, encouraged by Bush administration, is beginning to see new life in its once-moribund corner of the world. Capitalizing on high natural gas prices, fears of California's energy problems and what they say technological improvements, utilities are taking steps once thought inconceivable to expand the use of nuclear power. Utilities, meanwhile, are bidding against one another to buy aging nuclear power plants once widely viewed as white elephants. Rather than mothballing 40-year-old plants as had been anticipated, owners of 33 nuclear reactors are seeking 20-year license renewals from the U. S. Nuclear Regulatory Commission (NRC) [3]. While environmental groups continue to oppose nuclear power, other criticism from consumer advocates has melted away amid concerns about rolling blackouts and 400 $ a-month heating bills.

Nevertheless, the nuclear power industry in the U. S. continues to operate without a national storage facility for high-level radioactive waste. The chosen disposal site, Yucca Mountain in Nevada, is bitterly opposed by some Nevada officials, stalling its opening until at least 2010. In the meantime, some 2000 metric tonnes of waste produced annually by the nation's reactors is being stored at plant sites.

Just a few years ago, many analysts were predicting the end of nuclear energy in the United States. Many predicted that–in the face of electric industry competition–large numbers of nuclear power plants would be shut down before the end of their 40-year licenses and the amount of energy generated by U. S. plants would slowly erode. Many believed that nuclear couldn't compete–that U. S. utilities would turn away from their plants, largely forego license renewals, and invest in alternative sources of electric generation. However, reality has proven these forecasts to be incorrect. For the most part, it was always clear that the picture would be brighter than the worse predictions foresaw. But few, even those who closely watch nuclear industry developments, could have predicted the turn-around that is occurring today. There are three key reasons for this reversal of nuclear fortunes in the U. S.

- *Performance of nuclear utilities*. Little more than a decade ago, U. S. nuclear power plants were generating electricity only about 70% of the time. Nowadays, the average is approaching 90% [3]. U. S. nuclear plants rank high when compared with the nuclear plants of other countries and compare very favorably with other sources of generation in the United States. In fact, the average nuclear plant in the U. S. produces electricity at only about two cents per kilowatt-hour – far below the average U. S. market price and about the same as the most efficient natural gas-fired power plants. Moreover, the Energy Information Administration has just reported that U.S. nuclear power plants broke another record, producing more electricity in the year 2000 than ever before – despite the closure of eight less efficient units over the last decade.

- *Consolidation of the nuclear utility industry*. Because of the performance of U. S. plants, they have become attractive targets for acquisition. Large nuclear utilities in the United States are beginning to resemble the large nuclear-focused power companies in countries like Japan. Instead of many utilities owning one or two plants, there will soon be far fewer nuclear utilities, with each owning a dozen or more plants. This development not only provides for considerable efficiencies of scale in parts, training, and other aspects of operation, but it has two other benefits of possibly greater importance. First, as the best operators of nuclear plants acquire more plants, the performance of nuclear plants is likely to increase. Second, as in other countries which plan to build new plants, large utilities with majority nuclear generation have a long-term interest in nuclear power well beyond that of utilities that operate one plant as part of a larger system.

- *Successful management at the Nuclear Regulatory Commission*. Not long ago, many utility executives cited the unpredictability of regulation in the U. S. as a primary barrier to the construction of new plants in the U. S. and an obstacle to utilities seeking license renewals to operate their nuclear power plants for an additional 20 years. NRC has since that time shown itself to be a fair and effective regulator of nuclear industry. Thirty-three nuclear power plants are entering the renewal process now and informal contacts with utility executives now indicate that the overwhelming majority of U. S. nuclear power plant owners are planning to apply for license renewals for their nuclear units.

The existing U. S. nuclear power plants are successful both in terms of safety performance and in terms of economic competitiveness. The industry has made impressive strides to meet this condition, particularly over the last decade, through past programs to develop high-burnup nuclear fuel (which has enabled utilities to reduce their fuel costs by half, saving some 200 million $ each year) and to reduce occupational radiation exposures by 67% since 1985 [1]. Nowadays nuclear power is entering a new phase. As U. S. plants receive license renewals,

they must be prepared to operate for an additional 20 years – a total of 60 years – far longer than nuclear plants have operated to date. While license renewals confirm that safety will not be affected as these plants operate for a longer time, it is less clear what long-term operation means for reliability and cost-effectiveness. The application of advanced technologies can also continue the process of enhancing safety.

The current nuclear plants can continue to deliver reliable and economic energy supplies up to and beyond their initial 40-year license period by resolving open issues related to plant aging, and by applying new technologies to improve plant economics, reliability, and availability. The nuclear development program is cost-shared with industry and is conducted in close cooperation with the NRC. About 60 percent of funding is provided by industry and the suite of projects focuses on areas that industry would not have pursued on its own–projects that look at the long-term and focus on the need for a stable, reliable, non-polluting electricity source for the USA.

Are phase-outs real in the European Union?

Nuclear is the EU's largest single energy source for power generation, ahead of coal which is at 29% and gas at 15%. There are more than 140 power reactors in the European Union, producing around 35% of all the Community's electricity. Nuclear industry is strictly regulated and enjoys an excellent safety record – something the plant owners and operators are determined to maintain. Safety is the industry's top priority. Power plants operate safely and reliably, producing large amounts of electricity at competitive prices. They are environment friendly, as they emit no greenhouse or acid rain gases and their waste is safely managed. Many existing nuclear power plants have already been paid for. Their operating costs are therefore low, and the electricity produced is among the cheapest in comparison with other sources. Cost projections show that new power reactors will also be competitive, even assuming low gas prices and heavy subsidies for wind power.

Phase-out policies have recently been pursued by certain West European coalition governments for reasons that are purely political and ideological. The political decisions involved have not been based on safety, environmental or economic arguments, and have been out of line with public opinion. However, there is a strong belief that for the generation of bulk electricity, nuclear remains the only non-fossil energy source capable of expansion within Europe in the foreseeable future. The range of energy options available to EU member states is needed to be as wide as possible, while each nation has the sovereign right to make its own energy choices. The Green Paper recognises that individual countries have the right to choose nuclear if they wish. Each EU member state should also respect the energy choices made not only by other member nations, but also by countries that are seeking EU membership. The Green Paper and the ensuing debate have together created a solid basis on which to conduct future energy policy discussions. With security of energy supply now a major issue for the EU, the debate must go on without any single energy option being ruled out.

An opinion poll, conducted in France for the Union Française de l'électricité (UFE), has revealed that 86% of those questioned consider that "those who think the end of nuclear energy is imminent are wrong" [2]. A survey involving 1005 people was carried out during September 2002 by the public opinion study centre, CECOP (Centre d'études et de connaissances sur l'opinion publique). The poll also revealed that 59% of those questioned thought that nuclear energy was "the least expensive way to produce electricity". Approximately two-thirds of the participants in the survey considered that a phase-out of nuclear would have "negative consequences" for exports of electricity (67%), economic development (62%) and France's energy independence (61%). The survey also revealed some paradoxical attitudes towards nuclear energy among the participants, with 61% of those questioned saying that they did not want nuclear energy to be used in the future. A similar proportion said they would be prepared to see an increase of 3-10% in their electricity bills in order to "support the abandonment of nuclear energy" [20].

Nevertheless, Europe should not only reduce dependence on oil, it should also prepare itself for higher energy prices in the future. The price of oil and gas can only rise because of limited availability in the long run and higher costs of exploitation in less accessible areas. There are still problems in the field of nuclear energy, which remain to be solved. But the difficulties are being reduced and they do not justify the total phasing out of nuclear energy now carried out by a number of member states.

Many of Europe's nuclear plants will reach retirement age in the next 20 years. Atmospheric pollution and CO_2 emissions will surge, if the reactors are replaced by power plants that burn fossil fuels. Nuclear industry therefore makes a valuable contribution towards achieving Europe's economic, energy supply and environmental objectives. No single energy source can be "sustainable" by itself. However, nuclear can clearly contribute to a sustainable energy policy and to sustainable development. The nuclear energy option should be kept open and nuclear expertise should be retained, in order to:

- achieve a viable and diverse energy mix,
- control airborne pollution and hold down CO_2 emissions,
- maintain security of energy supply and energy independence,
- promote economic development and employment, and
- ensure the industry's continued success on global markets.

The European Commission, the executive arm of the EU, has drawn up a package of proposed new legislation related to the nuclear energy field. This "nuclear package" was formally presented to the European Parliament in Brussels on 6th November 2002 [21]. The package mainly consists of proposals for Directives covering the management of spent nuclear fuel and radioactive waste, nuclear safety standards in an enlarged EU.

Nuclear scene of individual countries

Belgium

The economic affairs committee of the Belgian parliament has recommended that a draft law aimed at gradually phasing out the use of nuclear power in the country from 2015 onwards be formally adopted. The recommendation was made by the committee on November 13, 2002. The parliament's Chamber of Representatives is expected to debate and vote on the committee's recommendation within the next few weeks. If the recommendation is adopted by the Chamber, the draft law will pass in the Senate.

France and Germany

The largest ever shipment of vitrified radioactive waste was returned by rail from Cogema's La Hague Plant in France to Dannenberg in Germany. From there, it was transferred to trucks for the final part of its journey to Germany's interim radioactive waste storage facility at Gorleben. The journey was marked by a series of protests from environmental activists, including protesters who chained themselves to railway lines. Others occupied the tracks in an attempt to stop the 1300 tonnes of radioactive waste reaching the storage facility. Only about 40 protesters took part – far fewer than the numbers involved in previous demonstrations [21].

Sweden

In 1997, the Swedish parliament took a decision to close Barsebäck-1 – which later closed in 1999 – and this was followed by a decision to close Barsebäck-2 by July 2001. The second closure was conditional on an increase in clean, alternative power generation capacity and a reduction in electricity demand, but those conditions have not yet been met. The current Swedish government favours a gradual phase-out of nuclear energy, similar to the policy adopted in Germany. Two new independent reports, commissioned by and submitted to the Swedish government, say enforced early closure of the Barsebäck-2 nuclear power unit could cause electricity shortages and lead to an increase in electricity prices. The Swedish government says it will now send the reports to approximately 100 different authorities, organisations and companies for review. The reports will form a solid basis for a decision by the government about the early closure of Barsebäck-2. Both reports state that early closure would result in increased power generation in Danish and German coalfired plants, prompting an increase in greenhouse gas emissions (and other pollutants). The reports also point out that the remaining "practical problem" is that closure of Barsebäck-2 at the end of 2003 would increase the risk of power shortages in early 2004 and perhaps also in the year after.

The United Kingdom

The UK carbon dioxide emissions are rising again, and Britain's existing climate change levy is expected to be scrapped and replaced with a carbon tax or system of CO_2 permits, which would suffice to make nuclear energy competitive. Such a tax would also support developments towards the real prospect of a wider application of hydrogen fuel cells. The climate change levy (which is also applied to nuclear energy in the UK) is not a cost-effective way of reducing the amount of carbon dioxide that is pumped into the atmosphere, as it is a tax on energy and not on greenhouse gases. Moreover, the levy does not apply to the use of fossil fuels by homes and transport and penalises electricity sources that do not produce greenhouse gases. The carbon tax or permit system should be applied to all producers of carbon dioxide, including the homes of private individuals, with compensation available to help more vulnerable members of the community. A carbon tax might initially be equivalent to an extra 1 penny (1.6 € cents) per kWh for electricity bills or 6 pence (9.6 € cents) more per litre of petrol [21].

A draft law dealing with the nuclear legacy created by Britain's early years of military and civil nuclear programmes will be published soon. The announcement follows The incident occurred in November 2002 when a small amount of radioactive material escaped and fell to the floor. The UK Nuclear Installations Inspectorate (NII) and the Scottish Environmental Protection Agency were informed, and the NII will now carry out an independent inquiry into the incident. The Dounreay site is currently undergoing decommissioning,

which is expected to be completed between 2026 and 2042.

Bulgaria

In Bulgaria the units 1 and 2 at Kozloduy are due to cease operation at the end of this year. The European Commission and the Bulgarian Government have confirmed the closure date for Units 3 and 4 of the Kozloduy nuclear power plant as originally agreed in a Memorandum of Understanding from 1999. This date, 2006, was confirmed in Brussels on November 18, and signals the provisional closure of the energy chapter of Bulgaria's EU accession process. The Commission has also agreed to carry out a peer review of safety of these units, but no link has been made between the outcome of this review and possible further discussion on the operating lifetimes of units 3 and 4. The future of Kozloduy is a highly sensitive issue in Bulgaria, as the plant accounts for about 45% of the country's total electricity production, and the general public strongly supports the use of nuclear energy.

Armenia

The Metsamor nuclear power plant, which provided almost 35% of Armenia's electricity in 2001, is operated by the Armenian energy ministry, with operational support from Russian enterprises and organisations. Russia will supply nuclear fuel in amounts necessary for the normal operation of the Metsamor nuclear power plant in Armenia. The venture to produce uranium in cooperation with Kazakhstan and Kyrgyzstan will start next year and would ensure a profitable business for all three parties. The project, originally agreed last year, will enable uranium concentrate to be mined in Kazakhstan, and then enriched at the Kara-Baltinsk works in Kyrgyzstan. The enriched uranium will then be transported to Russia.

Ukraine

Ukraine's parliament has ratified a state loan agreement with Russia for the completion of the Khmelnitski-2 and Rovno-4 (K2/R4) nuclear power units. More than two-thirds of members of parliament (314) voted in favour of ratifying the agreement, following an earlier recommendation by the parliament's finance committee [21]. The ratification came ahead of a new round of talks between Ukraine and the European Bank for Reconstruction and Development (EBRD) on the K2/R4 issue. Last year, Ukraine withdrew from an option to complete the two units with a loan provided by the EBRD, export credit agencies and Russia, because it was felt that certain conditions were "unacceptable".

China

By 2005, eight nuclear generating units with total capacity of 6600 MW are to become operational in China. Nuclear power currently accounts for only 1% of China's power supply, compared to 21.9% in the US, 33.4% in Japan, and 77.4% in France. Unit one of China's Qinshan phase three nuclear power plant site has been connected to the power grid. The unit, the first of two identical Canadian-style Candu units at the site, was connected to the grid on November 19, 2002. The project would greatly ease electricity shortages on the East China grid. The grid covers the provinces of Zhejiang, Jiangsu, Anhui and Shanghai, where demand for electricity is due to rise in the coming years. Unit one of Qinshan phase three is the seventh nuclear power unit in China to enter service and the fourth to start up within the last year. In a related development, it has been announced that grid connection of unit two of Qinshan phase two, which had also been expected at about the same time, had been postponed until 2003. The new plant at Yangjiang in Guangdong province will have at least four reactors, which is in line with China's tenth Five-year Plan (2001-2005), that includes up to six 1000 MWe reactors for Yangjiang [2].

India

The Indian Department of Atomic Energy has confirmed that first concrete has been poured at the site of two pressurised heavy water reactor units, due to be built at the Rajasthan nuclear plant site in Rawatbhata, northern India. The construction landmark for Rajasthan-5 and -6 came on October 17, 2002 [21]. The financial go-ahead for the two units was given by the Indian government earlier this year.

Japan

The Tokyo Electric Power Company has recently submitted an interim report to the Japan's Nuclear and Industrial Safety Agency (NISA) about comprehensive checks on the appropriateness of inspections conducted at its nuclear power plants. The company stated that a full examination of its nuclear facilities, ordered by NISA, had concluded that there was "no new fraud that could be a violation of technical regulations, or of the duties to report". A final report is due to be submitted in March 2003. In the wake of recent investigations into allegations of data falsification at Japanese nuclear power plants [21], NISA ordered the opera-

tion of TEPCO's Fukushima Daiichi-1 reactor unit to be halted for one year.

Kazakhstan

Kazakhstan is considering the import and storage of foreign low- and medium-level radioactive waste to help raise funds for a national waste disposal scheme and an environmental clean-up of its nuclear legacy. The proposal was launched in June 2001 as a result of limited available funds to pay for radioactive waste storage and restoration of areas contaminated by Soviet-era uranium mining and nuclear weapons testing. The project would cost the country approximately 1 billion US $. The International Atomic Energy Agency (IAEA) would be asked to oversee the package, transportation, storage and burial of the waste, as part of the proposed international initiative, which is currently being considered by the Kazakh government. The IAEA suggested the use of open pits – previously used as uranium mines – for the disposal of low- and medium-level radioactive waste, but it does "not encourage" Kazakhstan to pursue the import of radioactive waste, although it would be prepared to review the safety of the project on request.

CONCLUSION

Nuclear proved to be a secure, stable and abundant source of energy, as there are many conventional uranium sources around the world, and availability is not politically sensitive. Large stocks of fissile material are already available, and there are enough fuel assemblies (completed and in production) to provide for several years of normal nuclear power plant operation. Furthermore, the cost of nuclear electricity is not highly sensitive to the price of uranium. Fossil fuels have many industrial applications besides their combustion for electricity generation, while uranium has virtually no other practical uses, and its use in nuclear reactors, therefore, makes it possible to conserve valuable and finite fossil fuel reserves.

Nuclear power now plays an important role in reducing dependence on external energy sources, bearing in mind that greater use of nuclear power would reduce dependence levels still further. Each country needs an appropriate energy strategy, reflecting its natural resources and its energy needs. As virtually no carbon dioxide emissions are released from the nuclear fuel cycle, nuclear power will be needed to meet future targets for reducing greenhouse gas emissions. If the existing nuclear plants were phased out and replaced by other conventional generating plants, it would practically be impossible to achieve the Kyoto objectives of many developed countries.

In evaluations of life-cycle ecological impact, which burdens resource use, health effects and waste consequences, nuclear power out-performs other major energy options and ranks on a par with the best renewables. Despite long experience with nuclear power and the promising outlook for near-term deployment of new nuclear power facilities, there remain important challenges to expanding the successful application of nuclear technology. In particular, the public concern over the safety of nuclear plants must be fully addressed, as well as some of the barriers that must still be overcome to enable the countries to maintain a strong nuclear energy option for the future.

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Миодраг МЕСАРОВИЋ

КОНТРОВЕРЗНИ ПОВРАТАК НУКЛЕАРНЕ ОПЦИЈЕ

Нуклеарна опција је у јединственој прилици да успостави своју првобитну улогу основног енергетског извора захваљујући растућој пажњи која се поклања сигурности снабдевања електричном енергијом и новим прописима, посебно оним за спречавање климатских промена, који доводе у питање примену фосилних горива. Недавна светска догађања у погледу одрживог развоја указују на предност нуклеарне опције над другим изборима. Међутим, повратак нуклеарне опције замагљују бројне контроверзе. Оне су дискутоване уз посебну пажњу посвећену најновијим збивањима, укључујући Светски самит о одрживом развоју, одржан септембра 2002. године у Јоханесбургу, у Јужној Африци.