INSIDE

TECHNICAL CO-OPERATION

International Atomic Energy Agency

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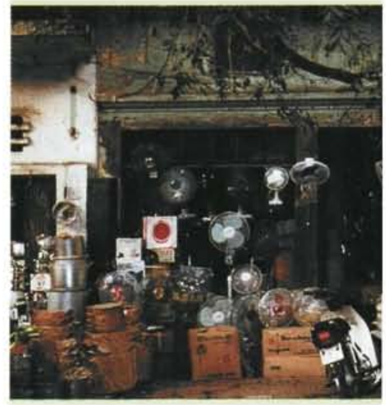
New Tools and Energy Choices

An adequate supply of affordable energy is critical to sustained economic growth; yet many developing countries lack either the natural, financial or technical means to ensure reliable supplies. Moreover, concerns about the impact of power generation on human health and the environment mean that countries must be able to assess and inter-compare all options in planning their energy systems.



Credit: L.Langlois/IAEA

Senior officials are participating in the energy planning programme (ENPEP). Demand for electric power is rising rapidly in Viet Nam. 40% of Viet Nam's population is below the age of 15 years. Credit: L.Langlois/IAEA

A project called DECADES was set up by nine international organizations including IAEA, to develop computerized tools (databases and methodologies) that can help national energy planners meet these challenges. In its first phase (1993-96) DECADES produced three databases and an analytical model called DECPAC, based on models such as ENPEP (for energy and power evaluation programme) jointly developed by the IAEA and the Argonne National Laboratory, USA. Using the personal computer (PC) based information package and the analytical model, national planners can compare energy systems on the basis of power production, as well as emissions of greenhouse gases and other pollutants, and add other elements to the analysis.

One DECADES database on "Reference Technology" covers all available primary energy power

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Technologies to Keep Spent Sources Safe

The analogy of building a brick wall is often used to illustrate what is meant by a nuclear safety infrastructure. In building up the basic foundations for safety in countries with only limited nuclear programmes, some bricks represent required legislation (on waste management and radiation protection), while others are the independent regulatory body with powers to ensure that the laws are obeyed. Still others represent technical capabilities and trained staff to handle all safety-related tasks.

IAEA activities have helped place the bricks in many countries, but some national walls still need strengthening. The focus of two separate but related multi-country IAEA technical co-operation (TC)

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Reactor Safety Top Priority in Former East Bloc

A full-scope simulator is used for training nuclear plant operators at the Balakovo training centre in Russia. *Credit: US Department of Energy*

Throughout the Cold War years, the nuclear power industry in the Soviet Union was effectively governed by considerations different from those in the West. Reactors were designed and built to respond primarily to requirements for reliability and availability. They were operated to produce efficient power, but regular shutdowns for inspection and maintenance were not required. Conditions then differed very significantly in terms of public participation, design and operation requirements, and notably in safety standards in general. Nuclear authorities today are addressing a number of serious issues.

The IAEA, together with several other international bodies and a number of individual countries, is involved in numerous activities to enhance the safety of reactors from that period. The main objectives are to rectify design shortcomings as much as possible by way of backfits and structural reinforcements, to improve operational efficiency, to strengthen and assist regulatory authorities and to nurture safety culture throughout the nuclear energy sector in the region.

Of the Soviet-designed reactor types, only WWERs (water cooled, water moderated energy reactor) were built outside the former USSR. The earliest types still in operation are WWER 440/230s (design capacity 440 megawatts, model 230). There are 11 of these units in operation in four countries: Armenia (1); Bulgaria (4); Slovakia (2); and four in Russia itself. These were designed before formal nuclear safety standards were issued in the Soviet Union and they lack basic safety features common in pressurized water reactors.

An important part of the IAEA programme addresses the safety of WWER 440/230 reactors. It is important to continue such activities into the foreseeable future because the problems will not disappear tomorrow, nor will their economic dilemmas. These countries are not likely to afford replacement power plants, nuclear or otherwise, for the next 10 years.

International involvement is also important to enhance and maintain safety and efficiency of other Soviet-designed reactors — the more modern WWER 440/213s and 1000s and the RBMKs — in operation. There are 14 WWER 440/213s in operation: Czech Republic (4); Hungary (4); Slovakia (2); Russia (2); and Ukraine (2). There are also 19 WWER 1000s of which only two (in Bulgaria) are outside the ex-USSR, while Russia has seven and 10 are in Ukraine. RBMKs are operating in Lithuania (2), Russia (11) and Ukraine (2 in Chernobyl).

An IAEA-coordinated international expert study, initiated in 1990, analyzed safety-related problems, both generic and plant-specific, in all these reactors and ranked them on the basis of safety significance. The findings have been a useful frame and guide for other Agency activities, including national and regional Technical Co-operation (TC) projects. They have also helped create linkages with a number of international programmes - notably of the European Commission, European Bank for Reconstruction and Development, OECD Nuclear Energy Agency, G-24, and World Association of Nuclear Operators - to upgrade the safety of these plants.

IAEA TC projects, especially those in eastern and central Europe, have focused mostly on enhancing national regulatory capability and improving plant safety. Under the Soviet Union almost all nuclear activities were handled by Russian experts. National regulators elsewhere in the region lacked both information about their plants and independence. Regulatory laws and regulations were inadequate. These countries are now addressing the issue and TC is helping them formulate adequate laws and regulations to give regulators the legal independence and authority they need, as well as to provide training and equipment. Projects to strengthen regulation were recently completed in Romania and Slovakia, and similar ones started in Ukraine and Armenia this year.

The most remarkable activity on the plant safety front led to the formal opening this April of a maintenance training centre at the site of the Paks nuclear plant in Hungary, complete with all the key parts of the core area of a WWER 440/230 reactor (see item on page 7). The full-scale mock-up reactor will help train and re-train plant maintenance staff, in the same way as simulators train operations personnel, not only those of Hungary but of all countries with any model of WWER reactor, bilaterally or through the Agency.

Regional Initiatives to Improve Plant Safety

In Agency efforts to improve the safety of WWERs, TC will continue to pursue country-specific issues through national projects. But an emerging trend is to mount regional programmes addressing broad issues that the IAEA identifies as common to a number of countries. This approach is by nature more proactive, in that it identifies opportunities for interventions rather than waiting for requests from governments.

Regional projects cover a variety of pertinent safety improvement issues of the older and newer WWER reactors. The problems addressed have been given high priority by the countries themselves. One project is to transfer advanced non-destructive testing (NDT) methods, over the next three years, to seven countries that wish to improve in-service-inspection (ISI) procedures. Croatia, has given the Agency free use of a laboratory and training facilities, complete with the required equipment to be used for training activities. The common methodology is a combination of workshops, discussions and hands-on training.

The nuclear power sector in the region is very different from what it was. Modern WWER 440/213s and 1000s are recognized for their high design quality. In older models still in operation, safety issues of the past are receiving priority concerns today. Upgrading programmes have been launched. Training and retraining for maintenance and operational personnel are now normal practices. Plant safety has replaced plant productivity as the driving aspiration. With continuing efforts, the rationale of all IAEA-TC projects, national and regional, is being fulfilled: to ratchet up safety levels without depriving the countries of the energy they need for continuing advancement.

Improving Nuclear Fuel Performance

A technician inspects the structure of a fuel assembly. The integrity of fuel assemblies under various conditions can be modelled using sophisticated computer codes. Credit: Framatome.

Nuclear fuel is made to order for various types of power plants and even for particular models. Good fuel performance is a key factor in cost-effective power production. It is also vital for operational safety, making it important for regulatory authorities to have in-depth knowledge of the design basis, fabrication history and characteristics of the fuel, as well as how it is expected to behave under various operating and accident conditions in the reactor.

Fabricating plants in many countries can customize fuel to particular specifications. Countries of central and eastern Europe which operate USSR-built WWER reactors traditionally bought fuel from Russia (which now sells only for convertible currency), but are now able to get supplies in the global market. However, long dependent on the Soviet Union, these NPP operators lack a comprehensive understanding of the fuel they use.

To help solve this problem an IAEA technical co-operation regional project (1995-96) was initiated to provide training and expertise for Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia and Ukraine, as well as key computer codes to assess fuel performance in various conditions and the database to conduct fuel modelling on their own. As a follow-up, a new two-year (1997-98) TC Model Project for the region aims to transfer knowhow to each of the eight countries plus Turkey — on licensing procedures and using computerized fuel modelling codes (systematic procedures to prepare mathematical models that represent actual circumstances affecting the fuel). The objective is that each national regulatory body will eventually carry out the licensing function independently.

The project targets utilities and regulators, as well as developers who will design and qualify national fuel codes. A project questionnaire is designed to identify the knowledge gaps and specific needs of the different countries at the outset. Training courses and fellowships will then be arranged to cover Agency guidelines on fuel safety, the national regulator's role in fuel licensing, Nuclear Safety Convention requirements, quality assurance of fuel performance and fuel fabrication and safety criteria for utilities and regulators.

Technologies to Keep Spent Sources Safe *(continued from page 1)*

Model Projects, launched this year, is to help consolidate radiation protection and introduce technologies for storing radioactive wastes in a safe manner.

Because radioactive wastes remain active and dangerous for long periods, technology for waste management is an essential part of nuclear infrastructure. It is not good enough to make certain, through regulation, that radioactive sources are handled with due care while they are being used, if they are then carelessly put aside when they are taken out of service and become waste.

Waste management technologies that are transferred to developing countries must match their needs and national technical capabilities. Project target countries typically make little or minimal use of radioisotopes. Most of them use sources only in hospitals and for some industrial work, such as radiography of welds. A few also have nuclear research institutions. Therefore, the project focuses on common sense solutions in five key potential problem areas.

The first urgent need is conditioning and storing spent radium needles. These tiny radium-226 sources were extensively used, mainly to treat cancers, all over the world for some 70 years. But their use has long been discontinued and replaced by more modern sources of ionizing radiation. Given radium's half life of 1600 years, the obsolete sources should be in long term safe storage until final disposal. Instead, the 15,000 or so identified in developing countries are often improperly stored, and some are known to be leaking.

The project is using a relatively simple technology to condition and store this waste. Uruguay is a prime example of a developing country in need of conditioning technology for its outmoded radium sources. All 150 needles and some old medical sources, containing some 2.6 grams of radium in total, had been removed from service and brought to its nuclear research centre (Marie Curie in the long and heroic research which later killed her, extracted only milligrams of radium from pitchblend).

Participants get hands-on training for conditioning of spent sealed sources at the Lo Aguirre Centre for Nuclear Studies in Chile. Credit: V. Friedrich/IAEA

The IAEA convened a team of three specially trained Brazilian experts to condition them. Under IAEA supervision the shielded source containers were opened, inventoried, funnelled into stainless steel capsules and the capsules welded. As part of the required quality assurance procedures, the welds were then leak checked. The capsules were placed in specially constructed lead shields which were emplaced for storage in 200 litre drums lined with some 500 kilograms of cement.

So all Uruguay's unwanted radium-226 is now in four safely stored, properly labelled drums, awaiting final disposal in a deep repository for very long half-life wastes, when one is established. Four more countries in the region and another in Europe have now chosen to go the Uruguayan route. Nicaragua, Guatemala and Jamaica are collecting all their needles in a single place, as required by the project. Later this year expert teams will repeat the process there that was done in Montevideo. Chile has begun training its own skilled team under the Interregional Model Project, to do the job itself. The project will also help Croatia become the first country in Europe to secure all its radium sources this autumn.

The second need addressed by the project is to make sure that less urgent sources commonly used in medicine and industry are also safely stored after they cease to be used and are regarded as waste. The isotopes - caesium-137, cobalt-60, iridium-192 and others - are not as long lived as radium. But they are intense and can be lethal. The ideal solution would be: Return to Vendor. A clause requiring the supplier company to take back spent sources may be written into future contracts. Even so, for sources already imported, as well for future imports even under take-back contracts, there may be obstacles to re-export. So the project will provide conditioning technologies similar to that for the radium needles. Eventual disposal in near-surface repositories, of the type existing in many developed countries, is adequate for these isotopes because they will decay away in a relatively short time.

Lax control or civil upheavals such as war can result in sources being abandoned, buried in rubble, and otherwise lost. The new project's third area is to trace lost sources, retrieve them and store them in a safe manner. Tracking down sources outside of regulatory control is technically straight-forward and cost-effective compared with the effects on public health and the costs of clean-up if they are damaged or mishandled. The project's fourth and fifth areas are designed for countries with larger nuclear programmes (those with research reactors or big hospitals) where solid and liquid radioactive wastes are produced regularly. Here the are produced regularly. Here the Model Project has a longer and more complex task: on the one hand to set up centralized processing and storage facilities; on the other to upgrade waste operator capabilities. Operator training is usually provided through expert missions sent to the country and through fellowships and visits to research centres in the region. A special new demonstration programme at selected national centres permits operators to not only see waste processing techniques being applied but experience working with real radioactive waste.

This year the project helped 10 operators from five Latin American countries to get such training at the Centre for Nuclear Studies (CEN) Lo Aguirre in Chile. Turkey's Cekmece Research Centre in Istanbul hosted trainees from four countries in Europe and West Asia. Plans are now underway to arrange hands-on demonstrations for the newly independent states of the former Soviet Union, and for countries in the East Asia and Pacific region. The technological bricklaying has already improved a number of infrastructure walls largely because governments, already aware of the problems, find the tools provided through the Model Project appropriate to their

Radioactive Decay & Half-life

Half-life is the period of time required for radioactive decay to reduce the inventory of a given isotope to half of its initial value. Decay is spontaneous, without any outside stimulus. The decay rate does not vary, so some isotopes with long half lives will be around for millions of years. Half-life is a key parameter in strategies and engineered structures for treatment and safe storage of radioactive wastes. Compared with the 1600-year half-life of radium-226, caesium-137, cobalt-60 and iridium-192 have half lives of 30 years, 5.3 years and 74 days respectively.

Nuclear Power's Contribution

Energy is perhaps the key controlling factor for economic growth and development in the next century. Endless statistics and thoughtful analysis estimate mind boggling energy requirements for the future, but the practical choices for sources of energy come down to a select few — each with its own consequences.

A total of 443 nuclear power plants are currently operating around the world. During 1996, five nuclear power plants representing 5717 megawatts-electric (MWe) net electric capacity were connected to the grid in France, Japan (2), Romania and the United States. In April 1997, Wolsong-2 in the Republic of Korea, a 650-MWe unit, was connected to the grid. During 1996, construction of three new nuclear reactors started — two at Qinshan in China, and one at Onagawa in Japan — bringing the total number of nuclear reactors reported as being under construction to 35 in 14 countries. Several Member States such as Viet Nam are exploring the feasibility of the nuclear power option with the co-operation of the Agency. Viet Nam has concluded that by 2010-2015, a nuclear power plant with a capacity of 800-1000 MWe should be introduced.

Nuclear power will continue to play an important role in the energy mix of many Member States over the next few decades. While most States favor renewable energy sources, the contribution of these sources to global energy demand today is limited to about 2% and likely to remain so for the foreseeable future. With the growing demand for energy and electricity, and the shadow of increasing concern over the greenhouse effect and acid rain, the nuclear power option will remain highly relevant to each State's energy mix — depending on a number of variables: the availability of other energy sources, the existence of adequate industrial and regulatory infrastructure, public acceptance and others.

Credit: Mitsubishi Heavy Industries

Worldwide in 1996, total nuclear generated electricity grew to 2300 terawatt-hours (TWh). This is more than the world's total electricity generation — 1912 TWh — from all sources in 1958. Overall nuclear power plants provided approximately 17% of the world's electricity production in 1996. Cumulative worldwide operating experience from civil nuclear reactors at the end of 1996 was over 8135 years.

All in all, 17 countries and Taiwan, China relied upon nuclear power plants to supply at least a quarter of their total electricity needs.

The decision to use nuclear power, conventional fossil fuel generated power, hydro, geothermal, or others, reflects a process of trade-offs. The role of the IAEA is to co-operate with Member States in making informed choices. These areas of co-operation include assessment of energy sources; technical support in areas such as safety, waste management, physical protection; quality assessment and control; energy planning; and training. The IAEA is the only international organization fulfilling this role, and is therefore an important partner for charting our energy future.

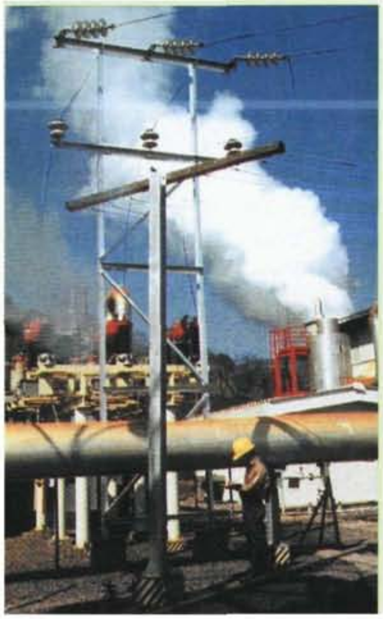
New Tools and Energy Choices *(continued from page 1)*

generation systems worldwide, and those expected in the next 20-30 years. A second global database, "Environmental and Health Impacts of Energy Systems," presents impact data, not only from power plants but along the whole length of each energy chain. A third provides a generic model for national databases, and can be customized by including country-specific information such as electricity demand in peak load, duration of load, hydrological conditions, committed additions and retirements of power plants, land-use or utilization of local fuels.

DECADES tools were transferred to some 35 countries in Phase-I through training courses involving both lectures and hands-on use. Some 80 trainees were provided with copies of the databases and DECPAC on diskettes, to share the experience with colleagues at home. Two or three trainees from a country participate at the same time; thus they could begin building country-specific studies during training. Most national databases have now been peer-reviewed.

Training in Phase-I was complemented by a three-year IAEA Co-ordinated Research Programme (CRP) that focused on national case studies to assess and compare the potential role of nuclear and other energy sources in reducing greenhouse gas emissions and other burdens on the environment. CRPs are designed so that all participants follow the same strict guidelines and present results that are comparable.

Phase-II of the CRP which began this year has two key objectives: to enhance the models and databases, and disseminate them widely. Databases will be extended to cover other pollutants such as heavy metals. Specific impacts of the different emissions - on human health, buildings, crops, and the environment — will be included and in due course quantified, ranked or weighted. Models will be elaborated to forecast future electricity demand in different countries. A CRP also has



Geothermal energy production in El Salvador. Credit: J. Perez-Vargas/IAEA

been established to compare electricity generating strategies in terms of their sustainability over time. Phase-II also is aiming towards examining the entire energy spectrum, as opposed to electricity generation alone.

Training is a vital part for disseminating the new tools, and the current goal is to graduate another 100-200 trainees during this phase. Once they master the methods, energy planners and decision-makers need to begin applying them in formulating real national plans. Brazil and Croatia will be the first two countries to apply the DECADES databases and the DECPAC model in developing their national plans.

Brazil's size combined with the existence of several independent and rival regional electricity utilities make the development of a coherent plan more than a little difficult. Electric power plays a crucial role in the economy of the State of Minas Gerais, which is based on manufacturing industries with heavy energy consumption. The State's energy utility (CEMIG) is already familiar with the ENPEP package, through an IAEA technical co-operation project completed in 1996, and now has considerable capabilities to carry out studies and make decisions for future energy needs. A new TC project, for which funding is still being sought, will enable CEMIG to use the DECADES tools in order to include health and environment factors in assessing electricity generating systems. At the same time the DECADES project will introduce its package to other utilities in the country.

An earlier TC project to help apply Agency power planning methodologies in Croatia has been extended (1997-98) to "enhance national capabilities for ... energy sector planning" as a whole. All relevant players in the country are involved in the activity, from the Ministry of Economic Affairs to university faculties and the power utility, the biggest oil company, national energy institute, and even some non-governmental organizations that promote emerging energies. One essential task is to do a comparative assessment of the different options to produce electricity, using the DECADES package. Two "graduates" of the DECADES approach have prominent roles in the working group that will conduct the study, scheduled for completion within 12 months.

Lithuania's electricity depends mainly on its USSR-built Ignalina nuclear power plant. A new TC project was started this year to help the national energy institute identify practical ways to expand power generation, using other primary sources and even other nuclear plants, as the country moves towards a market oriented economy. The project will introduce, train, and apply the basic IAEA planning methodologies (including ENPEP) on which DECPAC was developed. Elsewhere, in two on-going TC regional projects, 26 European and nine West Asian countries are taking part in workshops, technical forums and exchanges that provide training in ENPEP, thus laying the groundwork for using the DECADES package to develop environmental and people friendly energy systems in dozens of countries in the 21st century.

In Brief: Updates of Stories and News Events

Training Power Plant Managers

A regional course on management responsibilities in the training and qualification of NPP personnel, organized by the IAEA in co-operation with the German Government, will be held at the Forschungszentrum Karlsruhe, Germany, from 6 to 10 October. The 20-25 participants will be senior line managers of utilities, NPPs or regulatory bodies from IAEA Member States in the Europe region and among the CIS countries. Preference will be given to candidates from developing countries receiving IAEA technical assistance.

The course — held in Russian and English — will brief managers on their roles and responsibilities in training NPP operators. It will also introduce the systematic approach to training (SAT), demonstrate how this is applied at the Neckarwestheim NPP and also cover the establishment of national regulations, policies and procedures. Finally, it will focus on the transfer of experience by both lecturers and participants and contribute to consistency, efficiency and quality assurance in the training, qualification and licensing of NPP personnel.

Progress in TCDC

The IAEA's increasing emphasis on Technical Co-operation among Developing Countries (TCDC) was reiterated in its joint statement with four other specialized agencies of the UN common system at the 10th session of the High Level Committee on TCDC in New York early in May. Through its TC programme, the IAEA has stimulated private sector development, assisted in the transfer of technology and trained personnel at the national and the local level.

The IAEA encourages technical co-operation between its developing Member States mainly through three regional agreements for co-operation in research, development and training in nuclear science and technology. These agreements — in Africa, Asia and Latin America - aim to expand regional responsibility for programmes financed by the IAEA, other donors and the Member States themselves.

As a partner to developing Member States engaged in mutual technical co-operation, the IAEA provides co-ordination assistance and technical backstopping in a context of furthering regional self-sufficiency. For instance, the international campaign to eradicate rinderpest from Africa counts on the IAEA, in co-operation with some national veterinary laboratories, to verify immunization levels and to identify rinderpest-free areas. These laboratories also function as regional training and diagnostic centres, supporting the goal of a rinderpest-free Africa by the year 2000.

Paks MTC Inaugurated

A WWER 440/213 dummy reactor to be used as the centrepiece of a Maintenance Training Centre (MTC) at Paks NPP in Hungary (see "Old parts serve new purpose", Inside TC, December 1996) was formally opened on 29 April. The MTC is unique because it is the only full-scale WWER reactor - like those that produce 50% of Hungary's electricity — used for hands-on training. Improved training on actual components will reduce maintenance shutdown time and help to avoid mistakes. This will improve safety for maintenance workers, who will spend less time in a radioactive environment.

The project was funded mainly by the Hungarian Government and the IAEA (at a total cost of $10 million) and by extrabudgetary funds from Japan, Spain, the United States and the European Union through its regional programme PHARE. The IAEA donated the essential components, bought at giveaway prices ($1 million) from cancelled reactor construction projects in Germany and Poland.

The impact of the project will not be limited to Hungary. Eight other countries in the region have 45 WWER reactors in operation, providing one-third to one-half of their electricity. The training programmes and facilities at Paks can be used to train NPP maintenance personnel from these countries as well as the staff at Paks, thus contributing to safer reactor operation throughout the region. The Czech Republic and Slovakia have already concluded a training agreement with Hungary, and there is the possibility of the IAEA supporting training through TC fellowships and scientific visits.

Mr. S. Fazakas (left), Hungarian Minister for Industry and Trade and Mr. Qian Jihui, IAEA Deputy Director General and Head of the Department of Technical Co-operation, inaugurate the MTC at Paks NPP. Credit: M. Samiei/IAEA

Guarding Against the Seismic Threat

Earthquakes have been a continuing concern for the nuclear energy sector worldwide. In the early years of nuclear power, seismic knowledge was very limited. But understanding of earthquake behaviour, along with instruments and methodologies to measure many seismic phenomena more accurately, has increased vastly over the past 30 years. New knowledge has triggered strengthening of the safety barriers of many nuclear plants. For example, the Diablo Canyon plant in quake-prone California was upgraded to withstand a prodigious shock of 0.76g ("g" value is acceleration of gravity in seismic speak) as a result of a major US assessment programme.

The nuclear industry worldwide is committed to significant safety margins in nuclear power plants. Selecting a suitable site alone can consume more than five years of studies and US$10-15 million. A wide range of disciplines — geology, volcanology, historical seismicity and geophysics — is deployed. They focus on the immediate area (5 kilometres radius), further away (25 km) and finally as far as 200 km away, and thus postulate the magnitude of an earthquake at the site with a "return period" of 10,000 years.

It is only on this basis that the plant design is completed. The seismic design basis (SDB) specifies the engineering that can withstand an earthquake equal to the "g" value of the site. Requirements were far less rigid in the early years of NPP construction. And although there has been no substantial earthquake damage to an NPP in decades of nuclear power generation (over 8,000 years in sum), the industry is not complacent. With over 10 times as many reactors in operation (443) as are being built (35), the principal seismic effort is on upgrading existing plants.

The IAEA's seismic safety programme has helped countries like Indonesia, Iran, Morocco and Pakistan, with rigorous site selection evaluation for planned nuclear power plants. But the bulk of activities is in the former USSR and eastern and central Europe. Substantial work has been carried out to reassess the seismic design bases of WWERs in Armenia, Bulgaria, Hungary and Slovakia, most of them older models. These studies show that all the original design bases had underestimated ground motion parameters. So they must all be revised upwards, and upgrades must meet the new SDBs. Armenia's nuclear power plant has to be upgraded to meet a rating of 0.35g.

Twenty years ago, a severe earthquake in the shock-prone Vrancea region of Romania slightly damaged the two operating WWER 440/230 reactors in Kozloduy, Bulgaria, some 400 kilometres away. The ground motion was estimated to have reached 0.1g. A number of seismic safety improvements were then implemented in the two units and also introduced in the two units (3 and 4) under construction at the time. The new rating for the plant is 0.2g.

Two sets of data are needed to formulate or re-evaluate an SDB. One relates to earthquakes that have occurred, going back as far back in time as possible; the other analyses tectonic faults that can produce them. "In most eastern (European) plants they had used only recent seismic activity, not historical seismicity," an IAEA expert analyses. "The limited database was not sufficient for the purpose of designing an NPP."

The newly revised IAEA Nuclear Safety Standards (NUSS) combine the two data sets, enabling them to be used together to assess the seismic capacity (ability to resist shock) of these plants and define what upgrades must be done to achieve the reassessed design basis. The upgrades fall into two categories: so-called "easy fixes" which can be done quickly and relatively inexpensively, and structural upgrades which are long term and more costly. So far only Kozloduy and Paks (Hungary) have completed the "easy fixes", while structural upgrades have begun in one unit in Bohunice (Slovakia).

The IAEA requests that a methodical work plan is adopted in each country, and implemented according to its timetable. An earthquake magnitude under the new SDB is calculated with a return period of 10,000 years. So a country may decide that delaying completion of this work by a few years is a reasonable risk. But indefinite delay is too long to accept.

Bulgaria's commitment to upgrading nuclear safety at Kozloduy has been impressive and brought it dividends too. The IAEA technical co-operation project in Kozloduy (1991-95) included help to complete seismological studies, mostly in the country but also in the Romanian earthquake zone. The Agency also helped to upgrade the plant's seismic instrumentation. The Bulgarians, with technical help from the World Association of Nuclear Operators and funds from the European Commission's PHARE programme, elaborated and implemented the "easy fix" programme for Units 1 and 2. The country also did similar improvements on units 3 and 4, with support from the United States. The experience gained in the process, including the detailed preparations for the "easy fix" upgrading of the four units, has enabled Bulgarian authorities to draw up a comprehensive programme for the structural upgrading of the Kozloduy plant.

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