THE NUCLEAR POWER OPTIONS FOR AFRICA

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Abstract

Nuclear power is today only a small part of Africa's energy supply, but its contribution will grow in the future. The article elaborates on challenges associated with expanding nuclear electricity production in Africa, on possible ways forward, and on the range of assistance that the International Atomic Energy Agency can provide. For all its Members States, the Agency can assist in building national capabilities in overall energy analysis and energy strategy development. For countries wishing to pursue a nuclear power programme, it assists in planning, evaluating options and infrastructure development. Finally it assists at the stage of deployment and subsequent operation. For near-term progress in Africa, it will be necessary to bridge the gap between the economies of scale that favor large nuclear plants and the smaller electrical grids and capital capabilities of many African countries. Possibilities are, first, new small and medium-size reactor designs and, second, integration of electricity grids among neighboring countries

Introduction

Of the 440 nuclear power plants operating around the world today, just two are in Africa – Koeberg-1 and Koeberg-2 in South Africa. Koeberg-1 started operation in 1984 and Koeberg-2 in 1985. Both are 900 MW(e) PWRs.

⇒ Of the 24 nuclear power plants currently under construction around the world none is in Africa.

⇒ However, of the handful of promising new reactor designs now reaching the prototype stage, an important one is African – South Africa's Pebble Bed Modular Reactor (PBMR)

That is the situation now. But what are the possibilities for the future? First, let us look at electricity demand. It is clear that to reach the goals of sustainable development both electricity consumption and electricity production will have to increase significantly in Africa. Table 1 shows electricity consumption per capita for selected countries and regions, including several African countries. In general, values are highest for the Nordic countries, which have abundant hydroelectricity and long cold dark winters; for the small oil-rich countries; and for the geographically big OECD countries (Australia, Canada and USA). The lowest values are for countries in Africa, which had an overall average consumption of 514 kWh/cap in 2002. The African average is only 22% (one fifth) of the world average and 6% (one sixteenth) of the OECD average.

Table 1: Electricity consumption per capita for selected countries and regions.

	kWh/cap-yr
	2002
Ethiopia	27
Nigeria	72
Kenya	121
Ghana	300
Vietnam	383
India	421
Indonesia	428
African average	514
Egypt	1,120
China	1,208
Jordan	1,443
Latin American average	1,534
Turkey	1,559
Thailand	1,682
Islamic Republic of Iran	1,801
Mexico	1,832
Brazil	1,843
Argentina	2,082
World average	2,373
Chile	2,745
Poland	3,217
Hungary	3,545
South Africa	4,542
Russia	5,350
Italy	5,447
Saudi Arabia	6,103
United Kingdom	6,158
Korea	6,495
Brunei	7,316
France	7,366
Austria	7,453
OECD average	8,046
Japan	8,220
Belgium	8,314
Taiwan, China	8,841
Bahrain	9,649
Australia	10,502
United Arab Emirates	11,920
USA	13,228
Kuwait	15,102
Sweden	15,665
Canada	16,939
Iceland	27,764

Table 2 shifts the perspective from overall electricity consumption to nuclear power, and particularly to countries with plans to expand nuclear power significantly. The greatest projected nuclear power growth rates are in several developing Asian countries where annual electricity consumption per capita is currently small, specifically China, India and Pakistan. From the perspective of these countries, as shown in Table 2, expansion over a period of 30-50 years is needed to increase nuclear capacity by a factor of ten. Might a comparable future role for nuclear power be possible in Africa, and what possible technological and policy adjustments to current trends in nuclear power development would be most responsive to the needs of African countries? Might the PBMR, or some other innovative new nuclear power system, represent a technological leap-frogging opportunity for Africa, i.e. an opportunity to move directly to the next generation of nuclear power technology without repeating all the intermediate steps travelled by industrialized countries with long-established nuclear power programmes?

Table 2. Per-capita electricity consumption and projected nuclear power growth in selected countries and in Africa.

Country	Years	Annual electricity consumption, kWh/capita	Installed or projected nuclear power capacity, GW(e)	Projected growth in nuclear power capacity
China	2002	1,208	5.3	6-7 times
	2020		32-40	
India	2002	421	2.6	11 times
	2022		29	
Pakistan	2002	384	0.42	10 times
	2030		4.2	
Russia	2002	5,350	21	2 times (100%)
	2020		40-45	
ROK	2005		16.8	57%
	2015		26.4	
USA	2002	13,228	99	11%
	2020		~ 110 (?)	
Africa	2002	514	1.8	0-128%
	2020		1.8-4.1	

1. Nuclear Power Globally

There are 440 nuclear power plants in operation worldwide. In 2004, nuclear power supplied 16% of the world's electricity. This percentage has been roughly stable since 1986, indicating that, during the last 18 years, nuclear power has grown globally at the same rate as total electricity use. There are 24 new nuclear power plants currently under construction.

Most operating plants are in industrialized countries. 79% are in the OECD, 12% are in Russia and non-OECD Eastern European countries, and only 8.6% are in non-OECD developing countries. New construction, however, is concentrated in the developing countries. They account for 58% of the plants under construction. Russia and the non-OECD Eastern European countries account for 29%, and the OECD for only 13%.

Current expansion, as well as near-term and long-term growth prospects, is centred in Asia. Of the 24 reactors under construction, 16 are located in Asia. 21 of the last 31 reactors to have been connected to the grid are in the Far East and South Asia.

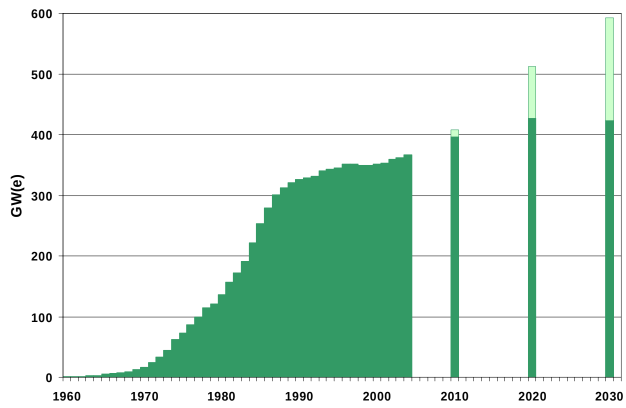
2. Rising expectations

After several years of having described global nuclear power development as 'on a plateau', IAEA Director General Mohamed ElBaradei shifted in 2005 to the phrase 'rising expectations' to describe the current global outlook for nuclear power. One reason is the announced nuclear power expansion plans of several key countries as shown in Table 2. In addition to these countries, in Western Europe excavation work began in 2004 for Olkiluoto-3 in Finland, a European pressurised water reactor (EPR) that will be the first construction start in the region since 1991. Also Electricité de France selected a site for a demonstration EPR, with construction expected to begin in 2007.

Revised Projections

A second indicator of 'rising expectations' is the upward revisions in new medium-term nuclear power projections released in 2004 by both the OECD International Energy Agency (IEA 2004) and the IAEA (IAEA 2004a). The IAEA publishes two updated projections each year – a low projection, which assumes that no new nuclear power plants are built beyond what is under construction or firmly planned today, and a high projection, which incorporates additional reasonable planned and proposed nuclear power projects beyond those already firmly in the pipeline. Figure 1 shows the updated 2004 projections together with the history of nuclear power expansion since 1960. The low projection was adjusted upwards for the fourth year in a row, reflecting an increasingly bullish outlook for nuclear power. The high projec-

Figure 1. Historical growth in worldwide installed nuclear power capacity, 1960–2004.



Source: IAEA 2004a

Note: IAEA's latest low and high projections through 2030 (low projections: dark green bars; high projections: light green bars).

tion was also adjusted upwards in 2004, although by a smaller amount.

Africa, however, is only a small part of the projected increases in nuclear power capacity on the right side of Figure 1. In the low projection, no new nuclear capacity is anticipated in Africa up to 2030. In the high projection an additional 5.4 GW(e) is anticipated to bring total capacity to 7.2 GW(e). Given Africa's low current installed nuclear power capacity, even this represents a quadrupling of capacity.

3. New Environmental Constraints

New environmental constraints, or more specifically, their economic impacts, provide a third reason for 'rising nuclear power expectations'. Russian ratification of the Kyoto Protocol in November 2004 triggered the Protocol's entry into force 90 days later — on 16 February 2005. Its limits on greenhouse gas (GHG) emissions should improve the economic competitiveness of all energy sources with low, or no, GHG emissions, including nuclear power and renewables. For nuclear power, GHG emissions are only 2–6 grams of carbon per kilowatt-hour for the full fuel chain (including construction of all facilities) — about the same as wind and solar power, and one to two orders of magnitude below gas and coal fired power. In the past, the low GHG emissions of nuclear power and renewables were irrelevant to private investors, as the virtual absence of restrictions or taxes on GHG emissions meant there was little economic value to their avoidance. Investors must now take into account the cost of GHG emissions, which will improve the competitiveness of new nuclear power plants relative to fossil fuel alternatives, notably coal-fired and natural gas-fired power plants. In May of this year the price of carbon emission permits rose to $86 per tonne of carbon in the European market, up substantially from earlier European values of the order of $30-40 per tonne of carbon prior to the Kyoto Protocol's entry into force.

Rising Energy Needs and Rising Energy Prices

Rising expectations for nuclear power are also driven by long-term projections showing persistently growing global energy demands. All independent analyses and forecasts project large increases in the century ahead — as a result principally of population and economic growth in today's developing countries.

Different countries face different demands and have different opportunities. For nearly all of them, the best energy strategy involves a mix of different energy sources, and for nearly all of them the best mix is different. It depends on national energy needs and how fast they are growing. And, as countries develop economically, final energy use generally shifts towards electricity. At the point of use, it is cleaner, more convenient and more flexible. Each country's energy mix also depends on national preferences and priorities as expressed in national policies. How countries trade off among considerations including environmental quality, jobs, occupational hazards, energy security and energy costs is at least partly a matter of national preference, and thus an area of legitimate disagreement — even where there is agreement as to the relevant facts.

But while every country's situation is different, we are all ultimately drawing from the same global resource base, whether it's oil underground or land available for biomass. So while we may choose differently from our neighbours, we are all affected by each other's choices. Prices are one measure of how each country's choices affect others, and recently rising prices suggest increasing competition in the foreseeable future for the same barrel of oil or the same cubic metre of natural gas. There may still be a lot of oil and gas in the ground, but increased prices suggest that no country can count on them being available indefinitely when needed.

4. Nuclear Power Economics

The answer to the question, "Is nuclear power economic?" is, "It depends." It depends on what indigenous energy resources a country has, on the available infrastructure and human resources, on the cost of the alternatives to nuclear power, on applicable environmental constraints, and on the country's energy security policies. Because new nuclear power plants are relatively expensive to build but relatively inexpensive to operate, it also depends on whether the investment environment requires short-term returns. Where governments are direct investors, they can generally take a longer-term view than can private firms in a liberalized market. Governments can also directly incorporate into their energy investment choices non-market considerations like energy security or environmental impacts.

IAEA Assistance: Energy Planning, Infrastructure Development and Deployment

A number of recently published global sustainable development scenarios show a substantial expansion of nuclear power. For example, the 'SD Vision Scenario' of the OECD International Energy Agency (IEA 2003) projects global growth in nuclear energy by a factor of 14 by mid-century, to approximately 5000 GW(e) in 2050. Much of this expansion takes place in developing countries, including African countries.

Such an expansion will require the development of nuclear power programmes in countries that do not now have them. For a country to introduce nuclear power, it needs to pass through three main steps: energy planning, infrastructure development and then deployment. The Agency assists Member States with each of these steps. It provides tools and assistance for energy planning; it supports infrastructure development; it provides support for effective deployment once a deployment decision has been made; and it provides a forum for assessing innovative nuclear energy systems (INSs) as a part of the Agency's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO).

With respect to energy planning, the IAEA helps interested Member States, often developing country Member States, build their capabilities for energy planning and analyzing energy systems. The Agency develops and transfers planning models tailored to the special circumstances of these countries. It transfers the latest data on technologies, resources and economics. It trains local experts. It jointly analyzes national options and interprets results. And it helps establish the continuing local planning expertise necessary to chart national paths to sustainable development. The IAEA is the only UN agency doing this kind of capacity building for overall energy-environment planning. Table 3 summarizes the basic energy models the Agency has available for transfer and training.

Demand for the Agency's models and services is growing due to increasingly complex energy systems, market liberalization, privatisation and environmental concerns. Thirteen country studies were completed in the past year, in Bulgaria, China, Haiti, India, Indonesia, Republic of Korea, Lithuania, Mongolia, Nigeria, Pakistan, Philippines, Sri Lanka and Vietnam. In 2005 we are beginning two new regional technical cooperation projects – one in Asia (with 13 countries) and another in Europe (three countries) – as well as six national projects: Azerbaijan, Columbia, Ghana, Guatemala, Nicaragua and Nigeria. A continuing project on Sustainable Energy Development in Sub-Saharan Africa includes Burkina Faso, Democratic Republic of the Congo, Ethiopia, Kenya, Mali, Mauritius, Niger, Namibia, Tanzania, Uganda, Zambia and Zimbabwe.

The Agency also conducts regular inter-regional training workshops -- held last year in the USA in partnership with the Argonne National Laboratory and in Europe at the International Centre for Theoretical Physics in Trieste – as well as regional training courses (two in 2004), national training courses (nine in 2004), and 'training the trainers' courses. One of the next regional training courses is expected to take place in Addis Ababa, Ethiopia in the Fall of 2005. The number of people trained in these courses has risen steadily in recent years and last year reached a record high of 231 energy professionals from 43 countries. The number of countries using Agency models is now 102.

After energy system analysis and energy planning, the Agency also provides assistance to interested Member States if and when they decide to start a nuclear power programme. A recently published document, for example, on Nuclear Power Programme Planning: An Integrated Approach (IAEA 2001) covers activities from the beginning of conceiving a programme up to the stage of a decision by the country to proceed with a project feasibility study at a specific site. It is addressed principally to developing countries that do not have nuclear power plants in operation or under construction, but are seriously considering the option – perhaps based on the sort of strategic analysis described above.

The Agency also provides guidance on proven engineering and management practices in establishing and enhancing a variety of infrastructure dimensions. Nuclear power infrastructure includes the institutional framework and legislation within which nuclear facilities operate and the industrial, economic, social, technical and scientific capabilities to enable the secure and efficient development, management and operation of nuclear power facilities. Given the infrastructural requirements for nuclear power, and given the current front-loaded cost structure of new nuclear power plants themselves, a country wishing to introduce nuclear power is faced with substantial initial requirements. The up-front infrastructure investments seem particularly daunting if a country initially needs only a relatively small amount of power from nuclear energy. The Agency has work underway to define the minimum infrastructure requirements, and the specific associated institutional or administrative steps. There is also growing interest in regional cooperation, and interconnected grids, shared facilities, shared education and training programmes, shared expertise in safety and operation, and shared skilled labour pools are all possibilities worth exploring, depending on the specific situation. The IAEA is preparing documentation on all.

With respect to the deployment stage, the Agency can assist with identifying technical possibilities and requirements prior to developing appropriate specifications. Agency assistance also covers the economic and finan-

Table 3. Principal IAEA energy analysis models

Model	Full name	Description
MAED	Model for Analysis of Energy Demand	Evaluates future energy needs based on development scenarios in a country or region
WASP	Wien Automatic System Planning Package	Identifies the optimal long term expansion plan for a power generating system within constraints defined by the user
MESSAGE	Model of Energy Supply Systems and their General Environmental Impacts	Optimises among alternative energy supply strategies for a country or region
ENPEP	Energy and Power Evaluation Program	Simulates alternative energy supply strategies for a country or region
FINPLAN	Model for Financial Analysis of Electric Sector Expansion Plans	Assess the financial viability of plans and projects
SIMPACTS	Simplified Approach for Estimating Impacts of Electricity Generation	Estimates environmental impacts and costs using minimum data input

cial analysis of potential nuclear power projects, and building up the necessary 'human resource' base through support for education, training and integration into the shared expertise of the global nuclear community. It can help in reviewing tenders and proposed designs. It can help with training and other preparations for plant construction, commissioning and safe operation. And it can provide training on a range of plant simulators to help trainees understand the fundamental behaviour of different nuclear power plant designs. The Agency also provides assistance in connection with some socio-political dimensions – effective communication with the public, for example, and information for policy-makers on broader international energy developments.

In all these dimensions, the Agency is very much aware that 'one size does not fit all'. Developing countries, and particularly those initiating nuclear power programmes, have different needs and situations than exist in countries with established programmes. Moreover, each new nuclear power country's situation is different from the others. The Agency's job is to help each interested Member State take full advantage of the global expertise and experience that has been built up, but also to facilitate the customizing of that experience and expertise to the particular interests of each Member State.

In addition to direct assistance, the Agency publishes a full range of technical documents that distil much of the world's accumulated expertise on all dimensions of nuclear power. They include guidance on planning, human resource development, regulation, construction, safe and efficient performance, full life-cycle planning, decommissioning, spent fuel and waste management. The IAEA maintains advisory groups that continually identify areas where it would be useful for the Agency to add to the existing body of knowledge, and help us assemble the appropriate talent and expertise. The publications are then a generally available resource.

Economies of Scale vs. Small- and Medium Size Reactors (SMRs) and Regionalization

Economies of scale argue for larger and larger nuclear power plants. Economies of scale also exist at the national level, as the greater the number of nuclear plants supported by the national infrastructure, the lower is the per unit (or per kilowatt-hour) cost of that infrastructure. However, economies of scale are only valuable where there exist the capital and electricity demand to take full advantage of them. And in many countries of Africa the necessary capital and electricity demand do not exist. For these countries, however, there are at least two routes by which a nuclear power plant might become part of a least-cost energy strategy that might be calculated using the IAEA models described above.

First is the option of small or medium-size reactors (SMRs). Small and medium-size reactors allow a more incremental investment than is required for a big reactor, and they provide a better match to grid capacity in countries with smaller grids. Consider the example of India, which has the most plants under construction of any country in the world. Six of the eight Indian plants under construction fall within the Agency's definition of small and medium-size. Four are 'small' (less than 300 megawatts), and two are 'medium-size' (between 300 and 700 megawatts). Although India is hardly a small country, its electricity sector has until recently been characterized by the development of smaller separate grids rather than a single integrated grid. SMRs have been well suited to these smaller separate grids. As a second constraint on power plant size, India's indigenous industry has until recently been able to manufacture turbines with a maximum rating of about 500 MW. Both these constraints are currently changing, and India is in the process of integrating its originally separate grids and taking on bigger nuclear power projects. In 2002 it began construction on two 1000 MW(e) WWERs (water cooled water moderated power reactors).

In addition to the Indian designs, several advanced SMR designs around the world are moving towards implementation. The Russian Federation already has a licensed design available for construction: the KLT-40, a 60 MW (e) reactor that can be floated and transported by barge, takes advantage of Russian experience with nuclear powered ice-breakers and submarines, and can also be used for district heating or seawater disalination.

The Republic of Korea has decided to construct by 2008 a one-fifth-scale demonstration plant of its 330 MW(e) SMART pressurized water reactor, which will also include a demonstration desalination facility. And South Africa recently approved initial funding for developing a demonstration unit of the 168 MW(e) gas cooled PBMR, due to be commissioned around 2010. Since the analyses done with the IAEA models described above generally have a planning horizon of around 20 years, the PBMR and other advanced SMR designs would be reasonable options to include in such analyses.

The second option, regionalization, has already been mentioned above. For several neighboring countries, each may find that nuclear power in not part of its least-cost energy strategy when the analyses are done separately. But when the least-cost strategy is analyzed for the group of countries taken together, it might turn out to include nuclear power. Regionalization can also generate advantages in terms of energy system efficiency and reliability. In most of the OECD, and particularly in the European Union, where grids are generally large enough to accommodate large additions, the trend is still toward greater grid integration for greater efficiency and reliability. Regionalization and integration may well be a desirable approach for some developing countries that do not individually have the capital access and grid size to take full advantage of nuclear power's economies of scale, but may collectively have the necessary capital access and grid size.

Innovation for Future Growth

If any technology is to survive and flourish in this century, continual innovation is essential, and it important that nuclear power innovations, research and development take full account of developing countries – both those with and those without existing nuclear power programmes. Innovation and R&D needs are different for developed and developing countries. And although today's developing countries may well dominate future markets for nuclear power plants, it is the developed countries that currently have the most R&D resources and expertise. An important challenge is thus to bring their resources and expertise to bear on the future needs of the developing countries through international cooperation.

Currently there are two principal multinational initiatives promoting international cooperation in nuclear power innovations. One is the U.S. initiated Generation IV International Forum (GIF). The other initiative is the IAEA's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO). It is open to all IAEA Member States and currently has 23 members: Argentina, Armenia, Brazil, Bulgaria, Canada, Chile, China, Czech Republic, France, Germany, India, Indonesia, Republic of Korea, Morocco, Pakistan, Russia, South Africa, Spain, Switzerland, The Netherlands, Turkey, Ukraine and the European Commission. INPRO's overall objectives, looking ahead 50 years, are:

- to help to ensure that nuclear energy is available to contribute in fulfilling, in a sustainable manner, energy needs in the 21st century,
- to bring together all interested Member States, both technology holders and users, to consider jointly actions required to achieve desired innovations in nuclear energy systems, and
- to create a process that involves all relevant stakeholders.

INPRO recognizes the importance of taking into account the special circumstances and needs of different developing countries – for example the common lack of strong technical and industrial infrastructures and the sometimes isolated and small grids. A number of the concepts of special interest to INPRO try to address these issues, including SMRs without on-site refuelling. In addition to the SMR advantages cited earlier of smaller incremental investment requirements and greater suitability for small grids, SMRs without onsite refuelling have two other potential advantages. For such reactors all unloading of spent nuclear fuel, and all loading of fresh fuel would be done in a supplier country with a full fuel cycle, and the spent fuel would remain the responsibility of the supplier country. The first advantage is that this would remove the need for each developing country to build a final repository for high-level nuclear waste. A second advantage is that an SMR, where all loading and unloading of fuel is done in a supplier country that already has a full fuel cycle, may well be more proliferation resistant than reactors with on-site refuelling. Given currently heightened concerns about nuclear proliferation, the more proliferation resistant a nuclear system is, the less international political resistance there may be to introducing it in countries currently without nuclear programmes.

A related alternative is that of straightforward fuel leasing. In this case refuelling occurs on-site, but the fuel is continually owned by the supplier country, and the spent fuel is the supplier country's responsibility. Again this would remove the need for each developing country to build a final repository for high-level nuclear waste. Although no such leasing arrangements currently exist for nuclear power reactors, there are precedents in the system of the former Soviet Union and its European customers prior to 1990, and in past leasing arrangements for research reactor fuel. The closest current approximation is the arrangement recently negotiated between Russia and Iran whereby the former will take back fuel it supplies to the latter, after the fuel has been used in the Iranian reactor now under construction.

If and when SMRs without on-site refuelling become available on the market, they would create the possibility of leasing arrangements covering not just fuel, but the reactor itself. And the leasing concept could be extended even further to leasing 'services' in the case where, for example, a barge-mounted SMR is used to supply electricity, heat and/or desalinated seawater while the supplier retains responsibility, not just for the fuel and reactor, but also for the full operation of the plant. Fuel leasing and other multilateral approaches to the nuclear fuel cycle to increase proliferation resistance are examined in detail in a recent report by a specially appointed group of experts to the IAEA Director General (IAEA 2005).

In its initial phases INPRO has developed a methodology for the holistic assessment of innovative nuclear energy systems (IAEA 2004b) that includes a focus on institutional and infrastructure arrangements that will make the initial adoption of nuclear power systems by aspiring countries simpler. The INPRO methodology can be used to analyse the appropriateness of alternative mixtures of reactor types and fuel cycles for the long term sustainability of using nuclear energy to generate electricity, desalinate seawater, produce hydrogen or generate process heat.

Current INPRO activities include:

- a joint assessment, based on a closed fuel cycle with fast reactors, carried out by China, France, India, Korea, Russia and Japan;
- an assessment of an INS for hydrogen production, by India;
- a study on the transition from LWRs to a Generation IV fast neutron system, by France;
- an assessment of the introduction of a nuclear block of 700 MW(e), by Argentina;
- an assessment of an INS for country with a small grid, by Armenia; and
- an assessment of the comprehensive DUPIC fuel cycle in the area of proliferation resistance, by the Republic of Korea.

The current stage of INPRO, labelled Phase 1B, will also identify the areas where the next stage (Phase 2) can be most effective. It is expected that these will include facilitating cooperation in joint research into technical, institutional and infrastructure developments that can prepare the route for an easier and more effective application of nuclear power systems in the future.

Conclusion

Each country faces a different set of variables when choosing its energy strategy, and energy decisions cannot be made on a 'one size fits all' basis. Nor can nuclear power be described as categorically 'economic' or 'uneconomic'. It will always depend on the situation and the alternatives. New nuclear power plants remain most attractive in countries and regions where energy demand growth is rapid, alternative resources are scarce, energy supply security is a priority, and nuclear power is important for reducing air pollution and greenhouse gas emissions.

New nuclear power plants will also always be part of an energy mix, complementing other energy sources, including renewables. In Africa, the first energy-related task of sustainable development is often defined as bringing energy, particularly electricity, to the millions of people without it. For the rural poor, the best promise may indeed be that offered by off-grid renewables, and the efforts underway for realizing that promise as quickly and broadly as possible should be applauded. However, rural electrification can complement those efforts, and for the urban poor, and the needs of ever expanding cities, the mix needs to include large centralized power generation to match large centralized power demand. Nuclear power can play an important role.

Nuclear power will certainly be a part of Africa's energy future. At the International Ministerial Conference on Nuclear Power for the 21st Century organized earlier this year by the IAEA in Paris and hosted by the Government of France in cooperation with the OECD/Nuclear Energy Agency, a number of African countries

Table 1: Electricity consumption per capita for selected countries and regions.

spoke eloquently of the importance to them of maintaining and developing the nuclear power option. Moreover, the conference's final statement concluded, "a vast majority of participants affirmed that nuclear power can make a major contribution to meeting energy needs and sustaining the world's development in the 21st century, for a large number of both developed and developing countries".

At least for the intermediate term, however, the extent of nuclear power's contribution in Africa will depend, at least in part, on the speed with which smaller advanced reactor designs like the PBMR are brought to market and the ability of neighboring countries to consider joint planning and investment strategies to realize mutually beneficial improvements in grid efficiency and reliability.

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