

Energy strategies and nuclear power in Latin America and the Caribbean: Sustaining development

Expanding nuclear energy's role over the next decades could help the region meet rising demand for electricity services

Latin America and the Caribbean are home to 8% of the world's people who together consume about 6% of the world's primary energy production. In the coming decades, the region — like most developing parts of the world — will face increasing demand for energy, especially electricity services.

Future energy requirements will depend on a number of factors, but population growth and evolving lifestyles are likely to be major driving factors. The increase in population will lead to rising energy demand even if *per capita* energy use — which now is relatively low — remains at the present level. The process of urbanization will most likely continue, centered around huge megacities such as Mexico City, São Paulo, Rio de Janeiro, Buenos Aires, and Bogotá. This will tend to increase the demand for energy and especially for electricity; it will also create more urgent environmental problems, calling for the adoption of more efficient and environmentally sound energy policies.

Since the region's energy intensity — the energy consumption per unit of gross domestic product (GDP) — is relatively high, there is considerable potential for greater energy efficiency in both the industrial and residential sectors. Substantial savings are possible through technological progress and voluntary policies. However, the GDP composition tends to be energy intensive and structural changes will take time. Therefore, even with the implementation of energy efficiency measures and conservation programmes, the energy intensity will remain

stable or continue to grow slowly. Furthermore, the improvement of energy efficiency requires investments that could be difficult to finance. Like other developing parts of the world, the region has limited financial resources and large needs for social and economic development and for repayment of previous loans.

Therefore, the region's primary energy consumption is expected to keep growing at a higher rate than the world average. Additionally, the demand for commercial energy sources will increase more rapidly since they will progressively substitute for non-commercial sources. Scenarios developed by the World Energy Council (WEC) show that the primary energy consumption of Latin America and the Caribbean will increase by a factor of 1.25 to 1.7 from 1990 to 2000, depending on economic and population growth and on the relative success of any programmes for energy efficiency and demand management. Over the period 2000 to 2015, the region's energy consumption would double according to the low scenario of WEC and triple in the high scenario. (*See table.*)

In the past, electricity demand has grown more rapidly in the region than has total primary energy demand. This trend is expected to continue because of rapid urbanization and industrialization. The region's average *per capita* electricity consumption is rather low compared to the world average. The demand for electricity services is far from reaching the saturation level in the residential sector. The electrification of rural areas will be necessary to enhance the quality of life and will add to the need for electricity generation, transmission, and distribution capacity. The structural evolution of the industrial sector is likely to favour the development of advanced technologies and modern production processes which are more

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Selected IAEA co-ordinated research programmes using nuclear techniques in health-related environmental studies

Years	No.*	Title
1984-89	14	The significance of hair mineral analysis as a means for assessing internal body burdens of environmental pollutants
1984-90	14	Human daily dietary intakes of nutritionally important trace elements as measured by nuclear and other techniques
1985-90	11	Nuclear techniques for toxic elements in foodstuffs (RCA Region)
1987-92	20	Use of nuclear and nuclear-related techniques in the study of environmental pollution associated with solid wastes
1987-92	10	Nuclear analytical techniques for the analysis of trace elements in agroindustrial products and foodstuffs (ARCAL Region)
1990-95	10	Assessment of environmental exposure to mercury in selected human populations as studied by nuclear and other techniques
1992-97	19	Applied research on air pollution using nuclear-related analytical techniques
1996-00		Assessment of environmental pollutants using radioimmunoassay and other related techniques
1995-00		Workplace monitoring and occupational health studies using nuclear and related analytical techniques
1995-00		Secondary (regional) reference materials for environmental studies **
1995-00		Environmental biomonitoring and specimen banking for developing countries **

* Number of participating countries

** Depending on availability of extra-budgetary resources.

Note: A more detailed overview of the IAEA's work in this field can be found in the Proceedings of the IAEA Symposium held in Karlsruhe, Germany, in 1992, *Applications of Isotopes and Radiation in Conservation of the Environment*. See this IAEA Bulletin's "Keep Abreast" section for ordering information.

timates affects 200 million people in more than 70 countries) as the snail vectors of the disease multiply in the irrigation channels. Similarly, in Kenya, the Mwea-Tebere irrigation scheme made the country self-sufficient in rice. But it brought malaria (a disease that WHO estimates affects nearly 300 million people in altogether 103 countries) to the area as migrants from the surrounding areas and mosquitoes from the lower basin of the Tana river both moved to Mwea-Tebere. In Brazil, the opening of the Amazon has led to explosive increase in leishmaniasis and malaria. The sandflies which were a component of the sylvatic cycle for leishmaniasis and the mosquito vector of malaria came into contact with immunologically ill-

prepared settlers from Brazilian towns who came to the Amazon to exploit new opportunities only to find themselves becoming new targets of the disease pathogens.

In areas such as the forests of Brazil and Colombia, information is often not available on which of the several mosquito species there are vectors of human malaria. In the early 1980s, a technique was developed to help control the disease — an immunoradiometric assay (IRMA) which uses anti-sporozoite monoclonal antibody labelled with iodine-125 to bind antigens of the sporozoite (the infective stage of the malaria pathogen which is carried by mosquitoes).

The method distinguishes the sporozoites of *Plasmodium falciparum* and *P. vivax* — the two most common forms of human malaria — from those which infect primates and other animals. It thus clearly identifies the mosquito species that carries human malaria. The subsequent study of the ecology and ethology of the vector enables the formulation of cost-effective control. Consequently, a species that breeds and rests in and around houses and feeds on humans may be controlled by spraying houses with pesticides such as DDT. If the vector were a forest dwelling mosquito, however, such a strategy would be ineffective.

When used with the malaria antigen NANP, the IRMA technique will measure anti-sporozoite antibody levels in humans. This antibody arises in response to inoculation with sporozoites through mosquito bites. Because of its short half-life, the antibody reflects malaria transmission in the previous 3 to 6 months. The test can be used to compare malaria transmission intensities in different areas, and to detect changes resulting from environmental modification or the application of control measures.

Industrialization and the associated migration from rural areas to cities lead to health concerns beyond those directly related to air pollution from motor vehicles and industries. It often means that migrants are concentrated in shanty towns where overcrowding and poor sanitation can cause the escalation of diarrhoeal, mycobacterial, and other diseases.

Easy access to pharmacies in many urban centres further can lead to the abuse of curative drugs and to the emergence of drug-resistant strains of pathogens. As they move into cities, people bring with them the vectors and diseases which until then had been limited to rural regions. Thus, in some countries in Latin America, for example, Chagas disease has entered cities. The main transmission route is no longer the triatomid bug, but blood banks where the poor sell their blood together with blood-borne diseases.

Argentina. Two nuclear units are in operation, at Atucha and Embalse; both are pressurized heavy water reactors (PHWRs). Atucha, which has a capacity of 350 MWe, was connected to the grid in 1974. The 650-MWe Embalse plant started commercial operation in 1984. Both units are operated by Argentina's nuclear energy commission (CNEA) and were imported from Germany and Canada, respectively. In 1992, the Argentine nuclear power plants provided 14% of the electricity supply of the country with a production of 6.6 TWh. A third unit is under construction on the Atucha site. Known as Atucha-2, the 600-MWe PHWR was imported from Germany and is expected to be in commercial operation in early 1995.

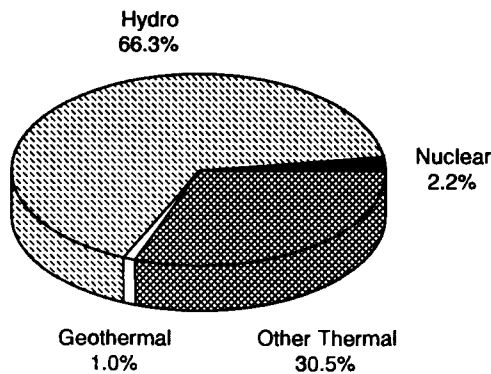
Brazil. One unit, Angra-1, is in operation, a 630-MWe pressurized water reactor (PWR) imported from the USA. It supplied less than 1% of the electricity consumed in the country in 1992. The second unit, Angra-2, is a 1250-MWe PWR imported from Germany. It is under construction and expected to start commercial operation in the late 1990s.

Mexico. The first unit of Laguna-Verde, a 650-MWe boiling water reactor (BWR) imported from the USA, started commercial operation in 1990. In 1992, it provided nearly 4% of the electricity supply of the country with a production of 4 TWh. The second unit, of the

same type and at the same site, is under construction and expected to start commercial operation in 1994.

Cuba. Two 400-MWe pressurized water reactors (WWER-440 reactors) imported from the former Soviet Union have been under construction since the mid-1980s and are expected to be in commercial operation in the mid-1990s.

Electricity consumption



Source: EnergyStatistics, OLADE, SIEE, Version No. 4, July 1992.

Nuclear power and electricity consumption in Latin America and the Caribbean

hydro locations to consumers in industrial and urban areas. Moreover, hydropower is highly capital intensive and its financing may be difficult in most countries of the region.

Fossil-fuelled power plants, using coal or gas, are well-established and economically competitive technologies. Rising concern about environmental impacts of burning fossil fuels has led to the development of advanced pollution-control technologies that improve efficiency, thus reducing carbon dioxide and other emissions per unit of electricity generated. Substantial progress has been achieved. These advanced technologies are already used in some Latin American countries and could be further deployed regionally, if they are given high priority.

Geothermal energy supplies 1% of the electricity in Latin America and the Caribbean. Biomass could be a promising source of supply in the future. Although its potential for electricity generation is limited, and the environmental impacts associated with burning organic compounds are far from being negligible, this option could be of significance in the region. This is especially the case in rural areas and in large

cities where it could hold ancillary benefits, such as helping the sustainable management and disposal of urban waste. The other renewable sources, such as photovoltaics or wind power, are not expected to make a substantial contribution to the region's electricity supply within the next two decades. This is because they still require considerable development efforts to reach the stage of commercial demonstration and economic competitiveness.

Nuclear power provides some 2% of the region's electricity supply. The technology is still in an early stage of development there. Only four countries — Argentina, Brazil, Cuba, and Mexico — have nuclear power plants in operation or under construction. (See box.)

Uranium production in Latin America and the Caribbean remains rather small, due to the prevailing conditions of the uranium market. Only two countries, Argentina and Brazil, are continuing to exploit their resources. However, the region's known and undiscovered resources are substantial, and more than 10 countries there have ongoing exploration programmes.

Argentina, Brazil, and Mexico have developed some activities in the nuclear fuel cycle industry. These mainly include uranium mining and ore processing, conversion and fuel fabrication, enrichment services, and heavy water production. This existing industrial infrastructure, together with efforts made in other areas of nuclear research and science, could serve as a basis for further deployment of nuclear power as a domestic energy source in the region.

Nuclear power prospects

Worldwide, nuclear power is the most likely non-fossil source of energy which can be deployed on a large scale and which is competitive for baseload electricity generation. Nuclear generated electricity is competitive and its relative competitiveness will increase when the environmental price tag is included in the cost of fossil-fuelled generation of electricity.

However, nuclear power is a demanding technology which has been developed mainly in industrialized countries, although a number of developing countries are already operating nuclear power plants and are planning to implement nuclear programmes. Issues of safety and radioactive waste management raise concerns that have to be addressed and public acceptance is a prerequisite for the implementation of sound nuclear power programmes. Designers are developing advanced reactors, building upon the extensive experience accumulated through the operation of the reactors of the present generation. Moreover, there is no doubt that the new generation of nuclear power plants will be better adapted to the requirements of developing countries, e.g. smaller size and easier operating and maintenance procedures.

In Latin America and the Caribbean, a broader development of nuclear power would contribute to enhancing the security of energy supply, developing advanced technologies, and implementing more environmentally benign electricity supply strategies. Since natural uranium and fuel-cycle services could be produced in the region, the development of nuclear power would allow the region to maintain its exports of fossil fuels and to diversify its energy supply using domestic resources.

Developing the industrial infrastructure for a nuclear programme involves the strengthening of a number of industries in the country to achieve maximum domestic participation. They include industries for construction, fabrication of equipment, and material and service supply. While some imports and transfer of technology will be required, the implementation of nuclear

programmes in Latin America and the Caribbean would benefit from the know-how and experience already acquired there.

The advantages of nuclear energy with regard to environmental impacts would be significant for Latin America and the Caribbean, especially in densely populated areas where atmospheric pollution raises concerns. It is expected that increased efficiency in electricity supply, transportation, distribution, and end use will play a major role in environmentally benign energy strategies in the region. The development of renewable sources will also be very important, especially in rural areas.

However, nuclear power could play a significant role. The latest projections made by the IAEA indicate that the total nuclear generating capacity of Latin America and the Caribbean could be multiplied by three or more by 2010, reaching some 6 to 8 gigawatts-electric (GWe). Nuclear power could then provide 2.5% to 3% of the region's electricity supply. (*See table and graph.*)

IAEA services and support

The introduction of nuclear power in a country requires a comprehensive planning and decision making process. It is based upon a series of interrelated studies covering energy supply/demand analysis, economic and financial analysis, and assessment of the infrastructures and manpower requirements and availability.

The IAEA provides information and support to its Member States for planning the introduction of nuclear power in their energy supply system when it constitutes a viable option. In the assessment, the specific social and economic conditions of the country are taken into account.

The IAEA has developed and made available methodologies and computerized tools, and offers assistance to interested Member States for conducting studies. The studies range from the pre-feasibility stage with an analysis of the overall viability of the nuclear option, to the detailed feasibility study of the nuclear programme, and finally to the planning and implementation of the nuclear power plants. The models include MAED (Model for Analysis of Energy Demand); WASP (Wien Automatic System Planning package); VALORAGUA, specifically designed for systems with a large share of hydropower; FINPLAN, which analyzes the financial aspects of power expansion programmes; and ENPEP (Energy and Power Evaluation Programme), which offers an integrated approach to energy and electricity planning, addressing health and environmental impacts. In

connection with making the models available to its Member States, the IAEA provides extensive training in the use of these tools to specialists from national organizations. Assistance for carrying out feasibility studies, bid evaluations, and financial analyses also is provided. Participation of specialists from Latin America and the Caribbean in the IAEA training programmes and technical assistance projects has enhanced the expertise available in the region for nuclear power planning. (See table.)

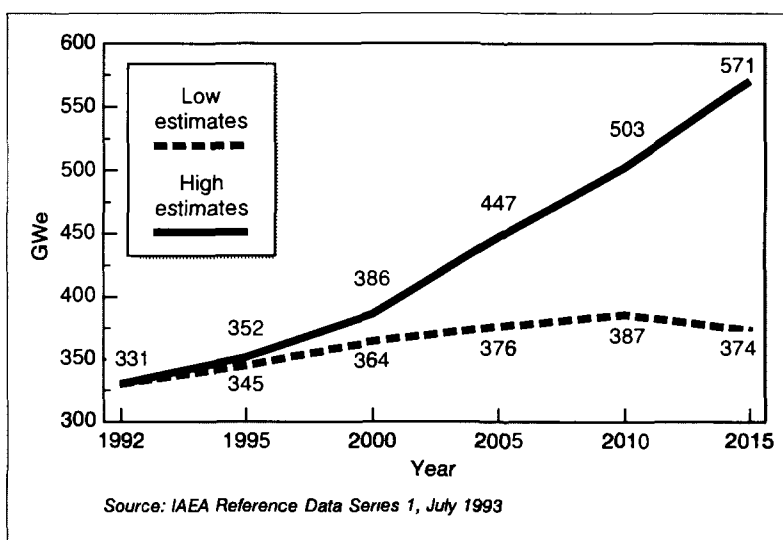
The methodologies and models developed by the IAEA have been transferred to several countries in the Latin American region. To date, 18 countries in Latin America and the Caribbean have received the WASP model; six have received the ENPEP model; three have received MAED; and three have received VALORAGUA. The models also are used by the Inter-American Development Bank (IDB) and the Latin American Energy Organization (OLADE).

National regulatory authorities are responsible for making the safety assessment of nuclear power plants and fuel-cycle facilities. For the purpose of enhancing the safety of nuclear facilities worldwide, the IAEA has initiated a number of studies and is providing services upon request to support the actions of national regulatory authorities. The IAEA's standards, guides, and practices on safety of nuclear power plants provide recommendations for national regulation and serve as a frame of reference for safety analysis, reviews, and assessment. Training programmes are provided by the Agency on safety issues to upgrade the personnel capabilities in this regard.

Need for co-ordinated efforts

Nuclear power already has contributed substantially to environmentally sound energy strategies over the past decades, and it has the potential to contribute a greater share to the electricity supply mix. Opportunities for further development exist in Latin America and the Caribbean, where environmental concerns are increasing and where natural resources and industrial infrastructure would allow a larger deployment of nuclear power. Comprehensive analyses of different energy sources for electricity generation indicate that nuclear energy is one of the most environmentally benign forms of energy, even significantly better than hydropower and other renewable sources.

In the Latin American region, nuclear power could play a role in sustainable energy strategies, based on comprehensive comparative assessment of different options that incorporate health



Year	North America	Latin America	Western Europe	Eastern Europe	Africa	Middle East & South Asia	SE Asia & the Pacific	Far East	World total	Projections of nuclear power capacity
1992	113.6	2.2	120.7	43.9	1.8	1.7	0	46.6	330.7	
1995	115.7	2.9	122.2	51.3	1.8	1.9	0	55.7	351.6	
	115.7	2.9	122.0	46.7	1.8	1.9	0	54.1	345.2	
2000	118.1	5.6	128.8	56.4	1.8	3.7	0	71.1	385.6	
	116.9	4.8	126.2	48.9	1.8	2.7	0	62.8	364.1	
2005	121.1	7.6	138.2	79.6	1.8	5.0	0.6	93.5	447.3	
	119.9	4.5	122.6	52.1	1.8	2.9	0	72.5	376.3	
2010	122.0	8.2	154.0	89.5	5.0	7.5	3.2	113.4	502.9	
	117.9	6.4	116.0	59.6	1.8	3.7	0.6	80.9	387.0	
2015	147.1	10.5	167.8	100.8	5.0	8.2	4.4	126.7	570.6	
	119.3	7.1	97.7	53.9	0	5.7	1.2	88.9	373.8	

Note: Data in gigawatts. The top and bottom figures are high and low estimates respectively

Source: IAEA Reference Data Series-1 (July 1993)

Interregional training course	Number of sessions	Number of participants*
Energy planning in developing countries with special emphasis on nuclear energy	8	250 (65)
Electricity demand forecasting for nuclear planning (MAED)	3	94 (21)
Electric system expansion planning (WASP)	9	227 (61)
Integrated energy and electricity planning for nuclear power development with emphasis on the ENPEP package	2	70 (24)

* Numbers in brackets indicate participants from Latin America and the Caribbean.

IAEA training courses on energy, electricity, and nuclear power planning

and environmental issues, as well as those related to security of energy supply and economic competitiveness. The region's social and economic development gives opportunities to introduce innovative policies and advanced technologies. The IAEA can continue to provide

information and support to enhance the capabilities of countries for implementing a nuclear power programme when it constitutes a viable option, taking into account the specific socio-economic conditions of the country.

Nuclear's future development undoubtedly will be dependent on its social acceptability. This, in turn, will depend on its acceptance worldwide especially in industrialized countries. Although it has been demonstrated that nuclear plants are safe when properly operated, the development of advanced reactors with enhanced safety features and planned measures for ensuring safe management and disposal of radioactive waste will be key factors. The role that nuclear power can play in alleviating environmental burdens from the electricity sector is worth the joint efforts of the scientific and industrial communities to facilitate its deployment. □



A market square in Guatemala. (Credit: J. Marshall, IAEA)

Highlights of Latin American energy conference

The Energy Conference of Latin America and the Caribbean (ENERLAC '93) was held in Santafé de Bogotá, Colombia, from 15 to 18 June 1993. It was organized at the initiative of the Latin American Energy Organization (OLADE) as a response to the need for analyzing the regional energy sectors development options, within the framework of the world's geopolitical and economic environment. The Conference was hosted by the Government of Colombia, whose President, Dr Cesar Gaviria Trujillo, opened the meeting.

The Conference was divided into four main modules: world geopolitics and energy markets; economic reform and the energy sector; energy, environment and sustainable development; energy sector and private sector initiatives.

Energy supply. According to the papers presented, the region's energy supply does not raise concern about the availability of energy resources; however, large investments are required, especially in the electricity sector, to meet the demand which is expected to continue growing despite conservation and efficiency enhancement measures. The inter-connection of electric and gas networks in the region will continue to be strengthened and will play a major role in enhancing the efficiency of the energy supply system.

Oil accounts for more than 50% of the region's energy supply. The region intends to remain a net oil exporter. Investments will be needed in the refining sector to increase the capacity for petroleum product production both for meeting domestic demand and to export to world markets. Gas is considered as an attractive alternative source, which is abundant in the region and could be developed on a broader scale for the regional market as well as for export worldwide. Coal contributes only marginally to the energy supply of the region; nevertheless, it is an important source in Colombia, Mexico, and Brazil and will continue to be developed with emphasis on clean coal technologies. Hydropower will remain a major contributor to electricity supply in most countries of the region. It is worth noting that biomass represents some 20% of the energy supply of the region and is expected to be developed further, using advanced technologies for processing and burning biomass products.

In several countries of the region, nuclear power is viewed as an alternative for the medium and long term; in this regard the role of the IAEA is important for assisting Member States, upon request, in their research and development activities and in assessing the viability and feasibility of nuclear programmes.

Economic factors. The ongoing economic reforms in the region, including the privatization of the energy and electricity sector, are expected to improve the technical and economic performance in production, distribution, and final use of energy. The governmental policies implemented in the past have proven to be far from the economic optimum; the tariff-setting policies, aiming in principle toward providing services affordable by all, led to insufficient earnings of the companies and lack of incentive to invest. At present, there are huge capital requirements for the energy sector which cannot be financed by the region alone.

The privatization of the energy sector, and the opening of the sector to foreign investors, should provide part of the funding for modernizing and adapting the infrastructure for producing and distributing energy, especially electricity, in the region; however, support from international development banks will also be necessary. Since private investors will design their policies in view of cost optimization, the result of the economic reform in the sector should be efficiency enhancement and improvement of natural resources management. However, concerns were expressed by some speakers regarding the willingness of the private sector to implement sustainable strategies in the long term; in particular, it was stressed that the governments should continue to play a lead role in planning and decision making in the energy sector in order to ensure a proper balance between short-term economic optimization and long-term objectives, such as energy independence and environmental protection.

Environmental considerations. There is growing interest in assessing the environmental impacts of energy strategies in Latin America and the Caribbean, like everywhere in the world. This was illustrated by the number of papers reporting studies on environmental impact monitoring, analysis of the status and trend in emissions from the energy sector, and assessment of alternative strategies for alleviating or mitigating environmental impacts. It was stressed that, while pollution problems do exist in the region, countries of Latin America and the Caribbean are among the lowest carbon dioxide emitters *per capita* in the world, essentially due to the large share of hydropower in the electricity generation mix. Conservation and demand management measures were presented as the preferred option for maintaining a low level of emissions and emphasis was put on clean fossil-fuelled technologies.