Cuba's Nuclear Program: A Hollow Threat?

By Jonathan Benjamin-Alvarado

On 28 September, Cuba gave up on a six-year campaign to attract foreign financing for the completion of two Soviet-designed nuclear reactors at Juraguá in Cienfuegos province. Initially conceived in the 1970s as a means of increasing electrical production capacity and diversifying energy sources, Cuba's nuclear power program had come to be seen by the late 1990s as a possible solution to the energy shortage triggered by the loss of highly subsidized petroleum imports from the Soviet Union.

Fidel Castro's recent announcement that work on the nuclear reactors has been suspended indefinitely has wide-ranging implications not only for Cuba's energy supply but also for the employment prospects of the island's scientific community and for future U.S.-Cuban relations. This paper investigates the political, economic, and diplomatic factors in Cuba's protracted attempt to develop a nuclear energy capability, as well as the implications of the termination of that attempt. Research for this paper included six field trips during which the author conducted more than thirty interviews with Cuban nuclear agency officials.

NUCLEAR ENERGY IN DEVELOPING STATES

Developing countries pursue nuclear energy under diverse circumstances and for different reasons, which can range from the perception of nuclear power as a relatively cheap energy source to the desire for a political symbol to enhance a regime's international prestige.

The benefits that may accrue from a national program of nuclear energy development include the following:

- *Low-Cost Energy*. Centrally generated electricity can be economically advantageous, and in some cases nuclear energy may result in the lowest real cost.
- *Energy Security*. Using nuclear power can contribute to the diversification of a country's energy sources, thereby diminishing dependence on the supply of any single fuel and/or reducing the need for imported energy sources.
- *Accelerated Modernization.* The successful implementation of a nuclear power program will both require and stimulate improvement in a country's technology, scientific competence, and industrial skills.

On the other hand, there are various costs, economic and otherwise, that may accompany a program of nuclear-power development, including the following:

- *High Investment Capital Requirements.* Whatever the real long-term expense of nuclear energy, creating and supporting the industrial and regulatory infrastructure needed for a nuclear power program commonly preempts a larger amount of available foreign exchange and investment capital in the immediate term than would be the case for a power generation system designed to use fossil fuels.
- *Increased External Dependence.* Although acquiring nuclear power can reduce dependence on imported fuels, a nuclear program may simultaneously generate increased dependence on external suppliers of materials, equipment, technology, services, and skilled labor.
- *Power-Supply Vulnerability*. In most developing countries, even a single reactor of minimal size would represent a large portion of the total electrical power

system, with obvious implications for the vulnerability of the system to the withdrawal of a single generating unit from service.

- *Brain Drain.* In addition to the actual financial cost of establishing and operating the administrative and regulatory institutions specific to a nuclear power program, such a program may carry a high opportunity cost by drawing personnel away from or preempting their entry into other productive sectors. Specifically, the tendency to draw a substantial portion of a developing country's best scientific, technical, and administrative talent into a highly centralized institutional structure may be socially, economically, and politically expensive.
- *Donor Disapproval.* Commitment to a nuclear energy program may make long-term economic sense to national planners, but if outside observers regard the program as an extravagant use of scarce resources in the short term, the country might have difficulty obtaining bilateral and multilateral assistance.
- *Increased Regional Tensions.* Objectively speaking, a comprehensive nuclear energy program is not needed for the production of nuclear weapons; a smaller dedicated program will suffice if military applications are the leading goal. Nevertheless, a program of civilian nuclear development may prompt distrustful or apprehensive neighbors to suspect an ulterior military motive, or to fear that the country might find it easier to produce nuclear weapons if it should decide to do so in the future.

Although the assessment of a potential nuclear energy program usually includes all of these factors, it generally starts with an examination of the relative economic merits of the various alternative means of generating electric power (e.g., nuclear energy, oil, gas, coal, hydropower, and perhaps more exotic, nondepletable sources such as wind, solar, or tidal energy). Although such a comparison is a complicated and contentious process, it ultimately uses familiar techniques of economic analysis. Factors to be taken into consideration include scale, location, costs, opportunity costs, energy security, energy efficiency, national development, and social impact. Specific to the nuclear power option are such concerns as whether a supply of uranium can be assured, what economic dividends might accrue from recycling plutonium, and whether adequate safety norms and fissile-materials protection/control/accounting procedures can be implemented.

Nuclear power proponents (basing their calculations on estimates of high-capacity nuclear plant operation) argue that nuclear-generated electricity costs less than electricity produced in other ways.

Table 1: Cuba's Potential Energy Output (1995)

MEANS OF GENERATION	POTENTIAL MEGAWATTS (MW)	PERCENTAGE
Thermoelectric	2,983.5	80.3
Hydroelectric	48.6	1.3
Gas Turbine	100.0	2.7
Industrial Plants	584.4	15.7
TOTAL	3,716.5	100.0

Note: In practical terms, the 1995 attainable peak outputs were much lower than the figures given here because Cuba could not afford to import enough petroleum to operate its power facilities at full capacity.
Source: Miguel Serrade t Acosta, *Programa Nucleoenergético Cubano* (paper presented at the Regional Seminar on Public Information, hosted by the Agencia de Energía Nuclear in Havana, 19 May 1995), p.3.

Skeptics counter by pointing to the enormous capital costs of nuclear plants (relative to coal-fired facilities), the failure of some nuclear plants to operate at expected output levels, and the existence of ample supplies of fossil fuels.

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Although both schools of thought tend to emphasize the role of economic rationality in the nuclear power decision-making process, psychological and political considerations are often equally important in a nation's decision to develop or expand nuclear power capabilities, as detailed above.

PREVIOUS ANALYSES OF CUBA'S NUCLEAR PROGRAM

Until recently, most of the research on Cuba's nuclear program was produced by the U.S. and Cuban governments. Although these publications were seemingly exhaustive in their coverage, the conflictual nature of U.S.-Cuban relations meant that almost all of them relied on secondary sources for information or were not corroborated by independent analysis.

The first comprehensive treatment of the Cuban nuclear program was a 1986 book by Fidel Castro Díaz-Balart, son of President Fidel Castro Ruz and then director of Cuba's nuclear agency. This lengthy work contained detailed descriptions of the planned nuclear complex's structure and functions as well as Cuba's long-term scheme for the development of

nuclear energy and nuclear science. Its ambitious tone conveyed the Cuban government's hope that the development of nuclear energy would prove to be one of the keys to economic development and modernization into the twenty-first century. In a follow-up volume published in 1990, Castro Díaz-Balart argued that the advantages of nuclear energy were so compelling that its development was essential to the nation.

A few academics have written specifically about Cuba's nuclear program, although there are almost no instances in which social science theory has been utilized to evaluate the program's wider implications.

Too often, the most high-profile treatments of this very technical issue have been so politicized as to be of little use in clarifying the true significance of the program within Cuba and internationally. Examples of this problem include the U.S. congressional hearings conducted in 1991 and 1995 to investigate the likelihood of a nuclear accident in Cuba. These highly partisan proceedings garnered much media coverage and played a major role in placing the nuclear issue near the top of U.S. concerns about Cuba. Rising unease in the West over the safety of the reactors led to a spate of press reports on the issue that often only reinforced the tendency toward sensational speculation rather than serious evaluation.

Around the same time, after defecting to the United States, José R. Oro, a geologist associated with Cuba's nuclear program, claimed that its real purpose was the development of weapons of mass destruction. In a 1992 book entitled *The Poisoning of Paradise*, he also argued that the Cuban government was disregarding standards and norms associated with the safe construction and operation of nuclear reactors, as well as environmental considerations, due to a lack of adequate resources. He warned that Cuba's use of nuclear power posed a serious danger to the environment in Cuba and beyond. Again, while some of these concerns may have been valid, their treatment is so politicized and Oro cites so little supporting evidence that it is difficult to evaluate the objectivity and reliability of his claims.

CUBA'S ENERGY SECTOR IN THE 1980S

During the 1980s, Cuba's annual oil consumption averaged 10.83 million tons, while the country's annual domestic production was only some 1 to 1.5 million tons. Under its trade arrangement with the Soviet Union, Cuba received up to 12 million tons annually, and the government resold the excess at world market prices in order to earn much-needed hard currency.

Cuba at the end of the 1980s had achieved three decades of impressive progress in the energy sector. . . .

Given this arrangement, it is not surprising that the Cuban government emphasized the possible economic benefits of nuclear power during the program's early years. In his 1986 book, Castro Díaz-Balart claimed that the first reactor, when running at full capacity, would allow the country to conserve six hundred thousand tons of oil annually, permitting greater quantities to be resold on the world market at a sizable profit. In addition to these revenues, it was believed that the reactor would give Havana a stronger bargaining position with the Soviets by lessening Cuba's dependence on imported oil.

The original Cuban-Soviet nuclear energy development agreement signed in April 1976 envisaged a network of twelve nuclear reactors across the island that would increase the island's energy generation capacity by 4,800 MW. (See Table 1.) In 1986, due to Cuba's resource and technological constraints, the plan was curtailed somewhat, with the revised version calling for three facilities (each containing two 440 MW units) to be installed in Cienfuegos, Holguín, and one of the western provinces. Altogether, these units were expected to increase Cuba's generating capacity by 2,640 MW, to a total capacity of almost 6,400 MW.

However, even with no operational nuclear reactors, Cuba at the end of the 1980s had achieved three decades of impressive progress in the energy sector, during which electrification was extended to

Table 2: Cuba's Electricity Production (in billions of kilowatt-hours)

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Electricity Production	12.20	13.17	13.59	14.54	15.24	14.68	12.74	11.13	11.05	10.98	11.19

Source: Organization for Economic Cooperation and Development (1996).

Table 3: Cuba's Electricity Consumption by Sector (in thousand tonnes of oil equivalent)

Year	Domestic Consumption	Energy Sector	Iron & Steel Industry	Other Industry	Residential	Non-Specified
1972	4,738	578		2,106	1,112	942
1973	5,133	635		2,281	1,166	1,051
1974	5,416	655		2,407	1,224	1,130
1975	5,925	758		2,633	1,311	1,223
1976	6,472	838		2,876	1,401	1,357
1977	6,935	889		3,082	1,581	1,383
1978	7,554	886		3,372	1,763	1,533
1979	8,493	1,030		3,788	1,975	1,700
1980	9,130	1,137		3,971	2,117	1,905
1981	9,726	1,037		4,669	2,042	1,978
1982	10,016	947		4,844	2,229	1,996
1983	10,133	991	103	4,760	2,344	1,935
1984	10,794	990	114	5,076	2,485	2,129
1985	10,529	697	128	4,895	2,682	2,127
1986	11,345	759	132	5,359	2,899	2,196
1987	11,644	796	145	5,534	2,912	2,257
1988	12,436	988	147	5,828	3,064	2,409
1989	12,955	1,055	143	5,936	3,252	2,569
1990	12,484	1,017		5,852	3,097	2,518
1991	10,921	813		5,158	2,730	2,220
1992	9,668	716		4,643	2,496	1,813
1993	9,596	714		4,625	2,480	1,777
1994	9,534	709		4,595	2,464	1,766
1995	9,714	722		4,683	2,510	1,799

Source: *Energy Statistics and Balances of Non-OECD Countries 1994-1996* (Paris: Organization for Economic Cooperation and Development, 1997), pp. 296-297.

the most remote regions of the island. Thermoelectric facilities were built, existing facilities modernized, hundreds of kilometers of electrical power lines installed, and hundreds of substations placed in a single interconnected 110 kV and 220 kV network integrated into the national electrical energy system. In 1988 the total gross production of electricity was 1,450 kilowatt-hours (kWh) per capita—more than three times the 1958 amount. (See Table 2.) One should keep in mind that these successes were possible largely because an energy grid was already in place when the Castro regime came to power, but the upward trend is impressive even so.

THE "SPECIAL PERIOD" DEATHBLOW

The relatively bright energy situation of the 1980s abruptly darkened in the early 1990s with the onset of the so-called "Special Period." As a result of the breakup of the Soviet Union and the loss of Eastern bloc support, the steady moderate growth of the late 1980s was followed by a roughly 25 percent contraction in the Cuban economy between 1990 and 1993.

The end of Soviet-supplied oil imports crippled Cuban electricity production, which fell by more than 26 percent between 1989 (when production peaked) and 1995. The severe drop in output resulted in nightly blackouts, problems with telephone service, and extensive shutdowns of factories and industrial projects throughout the island. (See Table 3.) As conditions worsened in the early 1990s, much work previously performed by machinery reverted to animal and human labor. (A positive consequence of this otherwise dismal situation was a dramatic reduction in environmental pollution throughout the island). The country has begun to experience a modest recovery in the past three years, but it still faces chronic energy shortages and

inefficiencies that could severely limit this recovery in the long term.

The nuclear program came to a virtual standstill in 1992 when the Russians withdrew funding for the construction at Juraguá and all other nuclear-related activities on the island. Following the cutoff of Russian funds, Havana looked for outside sources willing to commit the nearly $1 billion needed to complete the unfinished reactors at Juraguá. The government succeeded only in attracting a $30 million Russian grant, which was used to cover the preservation of work done up to that point at the site.

Most recently, President Castro effectively pronounced the nuclear program dead in a 28 September 1998 speech to the Fifth Congress of the Committees for the Defense of the Revolution. The Cuban leader announced that further construction of the Juraguá facility had been suspended indefinitely—for "a long time, a very long time."

MEETING TOMORROW'S ENERGY NEEDS

Meanwhile, a 1997 Castro announcement about the pursuit of other energy alternatives has been followed by renewed interest in Cuba's conventional energy sector on the part of foreign investors. Whereas Cuba was unable to attract adequate financing for the nuclear program, less risky energy development schemes such as thermoelectric, small hydroelectric, and biomass have been more successful in attracting investment and assistance. In 1998 alone, international firms have committed over $500 million to construct or modernize thermoelectric facilities.

To date, the United Nations Development Program (UNDP) and firms from France and Canada have also committed financing for small-scale energy development and expansion projects throughout Cuba. Although these will not be nearly enough to meet Cuba's growing energy demands, such projects may help Cuba to stabilize and diversify its energy supply somewhat.

On the other hand, by expanding its thermoelectric generation capacity, Cuba also raises its dependence on imports of oil. At a time when world oil prices remain low, thermoelectric generation remains attractive. However, this method already consumes almost 35 percent of Cuban export earnings and could become cost-prohibitive should world oil prices rise.

In addition, the anticipated expansion of generating capacity will necessitate complementary projects to bolster infrastructural support systems as well. Cuba's energy infrastructure is roughly fifty to sixty years old. Over the four decades since the Castro regime came to power, the Cubans have managed to improvise repairs using Soviet equipment and replacement parts that were often incompatible with the existing U.S.-built systems. However, it will soon be necessary to begin modernizing and replacing much of the infrastructure. There has been little discussion of the costs, scope, or time requirements of such an undertaking, yet it is reasonable to assume that the reconstruction will require a sustained twenty- to thirty-year effort and cost billions of dollars, easily surpassing the mere millions presently being pursued for energy generation.

Given the difficulties ahead, the role of the international community (including the United States) in Cuba's energy sector could be crucial. At some point in the future, U.S. firms and government agencies will presumably be less limited in their involvement. Those U.S. firms that have already established certified claims against the Cuban government for their former holdings in the energy sector would have a particular interest in exploring a possible return to Cuba, perhaps in a collaborative arrangement with the Cuban enterprises currently in possession of the properties in question. At the same time, multilateral and private lending institutions may find the rebuilding of Cuba's energy grid to be an attractive long-term project.

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In addition to boosting energy generation, the Cuban government is considering a number of measures designed to encourage energy efficiency and conservation in all sectors of the economy. The most draconian would require that all businesses (the majority of which are state-owned) pay their electric bills in hard currency rather than Cuban pesos. (Because the Cuban government maintains an artificially strong peso-dollar exchange rate, payment in pesos represents a substantial government subsidy.) Although the implementation of such a rule is unlikely due to the extreme resistance that it would meet, it is notable that the government is attempting to give companies (few of which have large hard-currency reserves) a real incentive to conserve energy, accompanied by real costs of failing to do so.

In February 1998, Ricardo Gonzalez, executive director of Cuba's national energy conservation program, expressed the hope that a vigorous conservation effort could result in savings of $37 million over three years, which would otherwise have to be spent on fuel imports. The conservation program, although only partially alleviating Cuba's immedi-

ate energy needs, bodes well for the future if properly implemented and could serve as a model for other national programs, especially in small developing countries.

CONSEQUENCES OF JURAGUÁ'S TERMINATION

In the short term, one clear effect of the nuclear program's termination is a loss of prestige for the regime. The Juraguá project had been trumpeted as the "Project of the Century," and the announcement of its indefinite postponement is a significant setback, even if only a symbolic one.

More concretely, the government must now address the problem of a corps of highly trained scientists and engineers who are left without jobs or purpose, a situation that could exacerbate domestic economic tensions.

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The government has been forced to deal with this issue to some degree since the Russians cut funding for the nuclear program in 1992, and has been resourceful in redeploying specialists to other tasks within the nuclear bureaucracy, such as translating technical documents into Spanish for the International Atomic Energy Agency (IAEA), hosting regional nuclear science conferences, coordinating regional information-sharing programs, and participating in efforts to bolster training and quality assurance for Cuba's ongoing nuclear activities.

Nonetheless, the implications of the decision to halt completely work on the Juraguá project will certainly limit the number of opportunities for professional development available within the scientific community, particularly on nuclear issues.

For those individuals unable to find other acceptable employment, the official end of the Juraguá project may increase the likelihood of emigration, exacerbating the "brain drain" that has already robbed the country of many of its brightest minds. There is also the possibility that some of these highly trained individuals could be lured into working for rogue nuclear programs in other countries set on developing weapons of mass destruction.

On the positive side, Juraguá's demise does remove one source of tension with the United States regarding national security and nuclear safety issues. Considering that the program was halted due to economic realities and not as a political gesture, and because it was only one of many areas of disagreement between Havana and Washington, it is unsurprising that the program's termination has not generated any conciliatory response from the U.S. government. At any rate, there is now one less stumbling block in the path should both sides at some point decide to move toward better relations.

U.S. CONCERNS IN PERSPECTIVE

Following the breakup of the Soviet Union, worries about the security implications of Cuba's nuclear program increased in the Americas, and especially the United States. One principal concern was that Cuba had not ratified the Treaty for the Prohibition of Nuclear Weapons in Latin America (known as the Treaty of Tlatelolco), which would have placed all of Cuba's nuclear activities under a full-scope safeguards regime and subjected its facilities to compliance and verification inspections by IAEA personnel.

Washington was also uneasy about the Cuban nuclear program's potential role as a conduit for lingering Russian economic and technical influence on the island and about the possibility of an illicit transfer of Russian know-how that might facilitate the later development of a nuclear weapons capability. Moreover, the questionable safety standards of Russian nuclear reactors lent credibility to the notion that a Chernobyl-like accident might occur, potentially threatening the greater Caribbean Basin.

Several recent pieces of U.S. legislation have therefore attempted to deter Cuba's nuclear program. Both the 1992 Cuban Democracy Act (the "Torricelli Act") and the 1996 Cuban Liberty and Democratic Solidarity (Libertad) Act (the "Helms-Burton Act") contain provisions directed at blocking third parties, including Russia, from funding and constructing the nuclear reactors at Juraguá. Specifically, the Helms-Burton Act instructs the president to

> withhold from assistance allocated, on or after the date of the enactment of this Act, for any country an amount equal to the sum of assistance and credits, if any, provided on or after such date of enactment by that country or any entity in that country in support of the completion of the Cuban nuclear facility at Juraguá. . . . [Title 1, Sec. 111]

Can the reduction of Cuban-Russian nuclear cooperation in the post-cold war period to a mostly symbolic level, followed by Cuba's recent decision to stop the Juraguá project, be credited to the success of a tough U.S. policy? Ultimately no. It is fairly clear that the Cuban nuclear program was brought to a standstill primarily due to both partners' shortage of hard currency.

In fact, the relevant provision of the Helms-Burton Act—aimed at breaking up Cuban-Russian nuclear cooperation by threatening Moscow with a reduction in foreign aid—contains exemptions for

the most significant area of assistance affecting Russia's nuclear industry: the aid earmarked under the Cooperative Threat Reduction Act of 1993 (the "Nunn-Lugar Act") (Title XII of Public Law 103-160) to help Russia stabilize its nuclear assets. Helms-Burton also exempts assistance in the areas of democratic political reform, free market system development, and humanitarian needs. In practical terms, this would have given Russia's Ministry for Atomic Energy a free hand to continue cooperating with Cuba and pursuing international reactor sales.

The IAEA Funds Controversy

Since the 1980s (when it held a seat on the body's board of governors), Cuba has been a very active member of the IAEA. Cubans have served as international safeguards inspectors, and the IAEA has provided a number of Cubans with safety-related advanced training. The organization has also sponsored regional seminars in Cuba for the exchange of information on applications of nuclear energy.

In February 1997, the U.S. media reported that funds contributed by the United States to the IAEA were being used to fund training for the Cuban nuclear program. A March 1997 study by the U.S. General Accounting Office (GAO) found that a portion of the voluntary contribution by the United States was indeed earmarked for technical assistance programs in Cuba. In 1996, about 30 percent of the IAEA technical cooperation fund was contributed by the United States. Therefore, it is reasonable to extrapolate that a little less than one-third of the $1.7 million approved by the IAEA in technical assistance for projects in Cuba for 1997 through 1999 would have come from U.S. contributions.

[A]chieving compliance with international safety standards has been a major Cuban priority in recent years.

Some months after the release of the GAO report, several bills and amendments were introduced in the U.S. Congress to withhold U.S. assistance for programs or projects of the IAEA in Cuba. (See, for example, H.R. 2092.) An exception would have been made for IAEA programs providing for the discontinuation, dismantling, or safety inspection of nuclear facilities or related materials, or for inspections and similar activities designed to prevent the development of nuclear weapons. However, this exception would not have applied to the Juraguá power plant or the nuclear research center at Pedro Pi unless Cuba ratified the Treaty of Tlatelolco or the Nuclear Non-Proliferation Treaty, negotiated full-scope safeguards with the IAEA not later than two years after ratification of such treaty, and incorporated internationally accepted nuclear safety standards.

Cuba's Focus on Safety Compliance

In reality, achieving compliance with international safety standards has been a major Cuban priority in recent years. In 1996, the government embarked on a nuclear law reform project (under the direction of the Agencia de Energía Nuclear and the Centro Nacional de Seguridad Nuclear) to complement that year's passage of Decree-Law 208 ("Regarding the National System of Accounting and Control of Nuclear Materials"). According to Cuban nuclear officials, Havana's delay in ratifying the Treaty of Tlatelolco stemmed from the need to alter the basis of Cuba's existing nuclear-relevant laws in order to bring them into greater harmony with the provisions of that agreement, with which Cuba fully intended to comply.

These officials were clearly cognizant of the shortcomings of the Soviet-based systems of accounting, control, and materials handling in the nuclear field, and they intended to design legislation that would promote adherence to internationally recognized standards and norms of nuclear materials handling and storage. In fact, the planned system was modeled on U.S. Nuclear Regulatory Commission standards.

If Cuba had continued with its nuclear program and successfully completed the nuclear-law reform initiative, Washington might have found it difficult from a diplomatic standpoint to oppose the island's nuclear development effort. Under the provisions of international nuclear accords and as a member of the IAEA, Cuba would have been entitled to pursue a nuclear energy capability so long as it adhered to provisions of full safeguards and nuclear safety protocols.

A Hollow Threat?

U.S. officials' concerns about the development of a nuclear energy capability in Cuba were understandable, given the potentially grave consequences should there be a nuclear accident, apart from any question of weapons development. However, the notion of Juraguá as an imminent threat to U.S. national security can be put to rest for two principal reasons.

First, Cuba is not and never has been in possession of nuclear fuel. Under the terms of its nuclear cooperation agreement with Russia, Cuba was to receive its nuclear fuel from that country, which also agreed to take back all nuclear waste generated by the Juraguá reactors. By the time the program was canceled, however, Russia no longer had the capability

to deliver nuclear fuel to Cuba, nor is it certain that the Russians would still have been willing to take back nuclear waste.

In addition, even if Cuba somehow became creditworthy overnight or found a willing financier, the reactors could be completed no sooner than early 2002, even in the absence of any significant delays. In all likelihood, completion would come even later, due to the need for backfitting and replacement of welding and parts. A more realistic estimate of the earliest feasible completion date would therefore be 2003 or 2004.

LESSONS FOR THE FUTURE

Although Cuba's nuclear program has effectively ended for the moment, the lessons drawn from the country's efforts to achieve a nuclear energy capability may significantly influence future energy development programs on the island.

The abandonment of an incomplete project has highlighted the ability of unanticipated events to undermine energy development schemes, and Cuba is likely to be much more cautious in how it approaches new energy-related projects. Future efforts to develop advanced energy generation capability, however attractive in the long term, may have to meet stricter financial, economic, and functional criteria before scarce resources are committed.

Even so, the existence of continuing energy challenges and a dormant but substantial nuclear infrastructure may eventually lead Cuba to reconsider the nuclear option. The failure of the Juraguá project may not deter the Cubans given the considerable amount of resources and capital already expended in the initial effort. One determining factor will be whether the project's human and physical infrastructure remains intact into the next century, given that Cuba's economic limitations will almost certainly restrict its ability to invest significantly in its energy sector for the foreseeable future.

The future Cuban economy—under whatever system—will continue to face energy challenges that significantly condition its potential for recovery and development. Cuba's vision of an economy with vibrant tourist and industrial sectors will be hollow without adequate sources of energy, and its ability to address the issue will have clear social and political as well as economic implications. Observers should therefore not be surprised if the nuclear energy option comes under consideration again at some point in the twenty-first century.

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DID CUBA MAKE THE RIGHT CHOICE?

Given the conditions prevailing during the Cold War and Cuba's close relationship with the Soviet Union, Havana's initial decision to pursue nuclear power was a rational one consistent with the social, economic, and technological imperatives the country faced. Reasonable justifications for the choice included the following:

· Adding nuclear reactors to the country's existing sources of electrical power would offer economic advantages. Although initially expensive, nuclear power had the potential for being Cuba's cheapest energy alternative in terms of long-range real costs.

· Once built, a nuclear power system would have helped Cuba to diversify its supplies of energy and thereby reduce its dependence on imported oil.

· A successful nuclear program would have been instrumental in raising Cuba's level of scientific and technical development in a number of other sectors.

Because the domestic economic crisis touched off by the end of the Cold War ultimately forced Havana to abandon the nuclear program, most of the aforementioned objectives did not come to fruition. Some critics of the program argue that, in hindsight, Cuba would have been better off expanding its thermoelectric capacity and rebuilding its aging conventional energy infrastructure rather than devoting more than $1 billion and decades of effort to the pursuit of its nuclear ambition.

At the time, however, Cuba had reason to believe that the project was viable, and the potential benefits seemed to outweigh the risk by far. Admittedly, with peak energy use on the island in the range of 1,300 to 1,500 megawatts (MW), the two 440 MW reactors at Juraguá could not have met all of the country's energy needs single-handedly even if they had been completed. However, a functioning Juraguá nuclear complex, together with the currently available flows of domestic and imported oil, would have made it possible to restore electricity production to pre-crisis levels.

Beyond the economic considerations, the social impact of the nuclear program has been mixed. Cuba dedicated a significant portion of its top scientific, technical, and administrative talent into the highly centralized institutional structure of the energy sector. While this did indeed result in the development of a highly trained cadre of nuclear engineers, technicians, and administrators—at a level quite impressive for a developing country—those individuals' skills and potential have for the most part remained untapped due to economic limitations.