The Economic and Developmental Implications of Cuba's Nuclear Energy Program

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I. Introduction

Since 1991 the Republic of Cuba has been attempting to keep its hope of developing a nuclear energy capability. Initially the program was conceived as a means for Cuba to increase its energy generation capacity and to diversify its energy generation sources. In the period since the end of the Cold War this effort has been focused on helping Cuba to offset the loss of oil imports from the former Soviet Union. This enterprise includes attempts to attract international investors capable of financing the completion of two Soviet designed reactors on the south-central coast of Cuba at Juragua in Cienfuegos province. Cuba has also been forced to deal with the accusation that lax regulations, shoddy workmanship and poor construction quality will result in the construction of a "Cuban Chernobyl." The Cubans counter these accusations with invitations to the critics (mostly American) to come and verify for themselves that Cuba is constructing a nuclear energy generation facility that meets and exceeds international standards and norms. The truth of the matter probably lies somewhere in between these two distant poles of contention.

This paper investigates the implications of Cuba's attempt over the past two decades of developing a nuclear energy capability. The primary research questions of this investigation are: (1) Why has Cuba selected the nuclear energy option? And (2) What are the economic and developmental implications of this pursuit? Utilizing the literature on nuclear energy development in developing states, the author details in a case study narrative, the circumstances under which and the reasons for Cuba's pursuit of this high technological capability. This helps in identifying the criteria by which a developing state may deter mine whether "commercial" nuclear fission represents a rational option for them. As a part of this process, each national case must be seen as unique, not only because national economies and resource endowments vary but also because the basis for assessing the socioeconomic and developmental costs of alternative energy strategies is necessarily peculiar to each national society. The analysis also provides a long-term perspective on the United States' national security threat posed by the construction of a nuclear energy reactor at Juragua and the potentially mitigating effect of international assistance to the Cuban nuclear program.

The author lays out the program's objectives in a costs and benefits analysis for the areas of economic and infrastructural development against the results some 15 years after the program was initiated. The research findings highlight both the negative and positive implications of the Cuban nuclear energy program. The program reflects favorably on the Cuban government's desire to integrate advanced science and technology in everyday Cuban life. This has resulted in a highly trained cadre of scientists, technicians and engineers dedicated to advancing Cuba's nuclear program. Research and development in this area places the Cubans among the leaders in the developing world. Conversely, the attempt has been undertaken at an enormous cost to the Cuban society. One of the original objectives of the program was to help Cuba in lessening its dependence on imported fossil fuels. As a result of pursuing and failing thus far to achieve the nuclear

option, Cuba remains highly dependent on these imports and has effectively shutdown its attempt to build nuclear reactors. Moreover, it now appears that the Cubans may have been able to meet it energy demands by constructing thermoelectric facilities, although this would have increased its imported oil dependence. Future prospects include the nagging need to boost Cuba's energy capacity in the face of a still weak economy and a deteriorating energy infrastructure, and the possible role to be played by international and American agencies to revitalize this sector of the Cuban economy. The evidence in support of this paper is based on 5 field visits by the author where he has interviewed over 30 Cuban nuclear agency officials, and review of official government documents. (See Appendix II)

The review of the relevant literature consists of a survey of the literature specific to the development of nuclear energy capabilities in developing states. The first section of the literature includes the key variables and indicators employed in the analysis. It also includes discussions of the relationship between energy, economy and security, and the limits of economic rationality in national policy decisions to pursue nuclear capabilities. The second section of the review discusses the literature specifically devoted to the study of Cuba's nuclear program.

II. Nuclear Energy Development in Developing States

States develop energy capabilities under a number of different circumstances and for a number of different reasons. The reasons can center on a developing state's ability to secure a relatively cheap source of energy or the need for political symbols which ostensibly extol the virtues of a given political and development regime. For some though this issue is no longer one of a relationship between nuclear power and economic development in general but rather one of identifying criteria by which a developing state may determine whether commercial nuclear fission represents a rational option for them. Under this approach the operative question is one of a cost-benefit analysis. The problem for developing states is to know what costs should be considered and what benefits should be considered, and by what standard (or under which measurement) they should be compared.[1]

When Ian Smart asserts that when any government or utility in a developing country is contemplating the development of nuclear power capabilities it would be wise to exploit (or at least to consult) other states' practical experience in planning, costing and operating nuclear plants. He continues, "to reject such evidence would be merely wasteful."[2] We should not assume that we are setting out to provide a quantitative analysis

1 Examples of this type of analysis are found in The Commission of the European Communities, Directorate-General for Energy and Development, *Energy and Development, What Challenges? Which Methods?: Synthesis and Conclusions* (Paris: Lavoisier Publishing, 1984); United Nations, Division of Natural Resources and Energy, Technical Co-operation for Development, *Energy Planning in Developing Countries* (Oxford, England: Oxford University Press, 1984); and Jose Goldemberg, Thomas B. Johansson, Amulya K.N. Reddy, and Robert H. Williams, *Energy for Development.* (Washington: World Resources Institute, 1987).

2 Ian Smart, p. 20.

and comprehensive assessment of the need for nuclear energy in a developing state. But it is prudent to consider these points qualitatively in a heuristic manner that edifies the analyst's flexibility with the details, nomenclature, and rationalizations used in the development of nuclear power programs. Simultaneously, as a part of this process, each national case must be seen as unique, not only because national energy economies vary but also because the basis for assessing the social and socioeconomic costs of alternative energy strategies is necessarily peculiar to each national society. From this we should ascertain that a cost-benefit analysis of nuclear power must be conducted indigenously and in terms relevant to that nation and society.[3] It may also serve as a template by which we can assiduously and prudently analyze Cuba's actions in the pursuit of a nuclear energy generation capability.

At this level of generality, all benefits that may accrue from a national program of nuclear energy development are familiar. They also serve as the focal objectives of any nuclear energy development scheme. They fall into three broad categories, The first of which is energy economics. In particular circumstances, centrally generated electricity may offer unique economic advantages, and after analysis the peaceful exploitation of nuclear energy may emerge as a means of generating electricity at the lowest real cost.

The second category is that of energy security. The introduction of nuclear power may help to diversify supplies of energy in general and electricity in particular, thereby diminishing dependence on any one source of supply and/or reducing dependence on imported energy sources. The last category, economic and technical modernization, refers to access to the advanced technology and industrial skills needed in a nuclear power program. It may be seen as a way of raising the level of scientific and technical development in a particular state, just as electrification based of the exploitation may be seen as an optimal path to economic development based on industrialization.4

Similar to the above-mentioned benefits, the apparent costs of nuclear-power development can be arranged in five broad categories: investment capital, external dependence, supplies inflexibility, institutional gravity, and energy intensity. These categories can be described in the following manner:

(1) Investment Capital–Whatever the real long-term cost of nuclear energy, creating and supporting a nuclear energy capability, with the necessary industrial and regulatory

3 Smart asserts that no general discussion of costs and benefits can pretend to be universally applicable. They can only point to broad categories of factors (which are numerous) that should be considered in every instance, but that should also be assessed individually by the government of each country as to their relative importance (p. 21).

4 Ibid. For a fuller discussion of the dynamics of the process of technological advancement and economic development, see Edward J. Malecki, *Technology and Economic Development: The Dynamics of Local, Regional, and National Change* (New York: Longman Scientific and Technical, 1991); see also the Organisation for Economic Co-operation and Development (OECD), *Impacts of National Technology Programmes* (Paris: OECD, 1995); Gerald Silverberg and Luc Soete, eds. *The Economics of Growth and Technical Change* (Brookfield, VT: Edward Elgar Publishing, 1994); and Pradip K. Ghosh, ed. *Energy Policy and Third World Development* (Westport, CT: Greenwood Press, 1984).

infrastructure, commonly pre-empts a larger share of capital in whatever form available for investment in energy supply systems–and also of available foreign exchange–than does a generating system designed for fossil fuels.

(2) External dependence–Whereas one motive for acquiring nuclear power may be to reduce dependence on imported fuels, gains in that regard have to be set against the extent to which a nuclear program entails additional dependence on external suppliers, notably in the developed world, for materials, equipment, technology, services, and skilled manpower.

(3) Supply inflexibility–In almost any developing country, even a single reactor of a minimum size would represent a large proportion of the total electricity system, with obvious implications for the vulnerability of the system to the withdrawal of a single generating unit from service.

(4) Institutional gravity–In addition to the financial cost of establishing and running the administrative and regulatory institutions specifically needed in a nuclear power program, the tendency for such a program to draw a substantial proportion of the best and the brightest scientific, technical, and administrative talent in a developing country into a highly centralized institutional structure may be regarded as socially, economically, or even politically expensive.

(5) Energy Intensity–Energy intensity *(I)* is defined as the ratio of the primary energy consumption *(E)* (measured in tons of oil equivalent) to the gross domestic product (GDP) (measured in thousands of dollars at a given year of reference). Frequently only commercial energy is used in calculating the energy intensity. The concept of energy intensity is proving to be useful in analyzing trends in energy consumption and their implications in a number of developing countries.[5] The implications are relevant to this analysis because modern technology is an extremely powerful factor in the way energy is used and economic activity develops in a state such as Cuba. Moreover, if the GDP in a developing state grows the only method of offsetting the resulting increase in energy growth (and the emission of pollutants and greenhouse gases associated with it) is to have decreasing energy intensity.[6]

Commitment to a nuclear energy program may make long-term economic sense to national planners, but if outside observers regard it as an extravagant use of scarce resources in the short term, the country might have difficulty in obtaining bilateral and multilateral assistance. Alternatively, a program of civilian nuclear development

5 Jose Goldemberg, "Communication: A Note on the Energy Intensity of Developing Countries," *Energy Policy* (1996) Vol. 24, No. 8, pp. 759-761.

6 For example, in the OECD countries, GDP has grown 3.7% per annum (pa) in the period of 1981-1991 and energy consumption grew on 1.4% pa since the energy intensity has been decreasing 2.3% pa. In contrast in Latin America has grown only 1.8% pa but energy growth was 2.9% pa because the energy intensity increased 1.1% pa. See Goldemberg, p. 759. See also L. Nielsson, "Energy Intensity in 31 Industrial and Developing Countries, 1950-1988." *Energy* Vol. 18, No. 4 (1993), pp. 309-322.

undertaken by a country that is itself embroiled in regional conflict may prompt suspicious or apprehensive neighbors to suspect an ulterior and more nefarious military motive, a possibility given credence by several current cases.[7] There are also less tangible, measurable and predictable costs that may have to be considered. There is the possibility that, even in the absence of any current intention to produce a nuclear weapons capability, by developing a nuclear power capability may seem to open an option to produce them in the future. Indirectly, the motivation for embarking on a nuclear energy development program may be bolstered by a sense of available benefits of increased international prestige, status and influence, of which commentators from developing states and the nonproliferation community have often spoken.[8] "How real those benefits are must be a matter of opinion since the evidence is confused and conflicting."[9]

Any consideration of the "quantifiable" cost and benefits in any national case must involve a parallel assessment of their probable effects in an unusually wide range of contextual settings:

(1) There is a distinction to be drawn between the domestic policy context and the context of international circumstances and relationships;

(2) The domestic policy context has to be sub-divided because "any national decision about nuclear energy touches questions, not only of energy supply and economic planning, but also of scientific and technological development, in the broadest sense, and even of social organization.[10]

The implications of a nuclear energy development program reach far beyond the scope and field of energy as such. Nonetheless, it is within this context that a national assessment for the consideration of nuclear power must begin. Having established the basis for this consideration, the first question to be addressed by national policy makers is what role electricity will occupy in the country's future energy system. "That is arguably an even more difficult question to answer in developing than in a developed state because it involves issues of both demand and distribution, which are likely to be volatile in a rapidly changing society."[11] This requires that an extremely detailed and convincing analysis of probable electricity demand over a future period of at least thirty years is available before the consideration of supply and energy options can reasonably begin.[12]

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7 I. Smart, p. 22.

8 See Jorge Sabato and Natalio Botana, “La ciencia y la technologia en desarrollo futuro de America Latina,” *Arbor: ciencia, pensamiento y cultura* (November 1993) Vol. 146, No. 575, pp. 21-43; Jorge Sabato, *Ciencia, desarrollo y dependencia* (San Miguel de Tucuman, Argentina: Imprenta de la Universidad de Tucuman, 1971); and Fidel Castro Diaz-Balart, *Energia Nuclear y Desarrollo: Realidades y Desafios en los Umbrales del Siglo XXI* (Havana, Cuba: Editorial de Ciencias Sociales, 1990).

9 I. Smart, p. 22.

10 Ibid., p. 23

11 Ibid.

12 This specifically requires that national planners have constructed a picture of expected geographical and sectoral incidence of demand. The next step must be to examine how energy demand can be

The consideration of the nuclear power option in a developing country now becomes possible through comparison of the various alternative means of generating electric power. The comparison of the peaceful exploitation of nuclear energy with oil, gas, coal, hydropower or other renewable sources such as wind, sun, and waves is a complicated and contentious process, but it is not one that requires any unfamiliar economic technique of assessing viability.[13] There are particular characteristics of nuclear energy that have to be taken under advisement, most of which fall conveniently into the categories of scale, location, costs, opportunity costs, national energy security, the promotion of energy efficiency,[14] national development and the social implications of such an undertaking.[15]

On the Relationship between Energy, Economy and Security.

The development of centrally generated electricity may offer unique economic advantages, and after careful analysis, nuclear fission may emerge as a means of generating electricity at the lowest real cost. The introduction of nuclear power may help to diversify and augment the domestic supplies of energy in general, and electricity in particular, thereby diminishing dependence on any one source of supply and reducing the dependence on imported energy sources.[16] In particular circumstances centrally generated electricity may offer unique economic advantages in comparison to other real cost. The introduction of nuclear power may help to diversify and augment the domestic supplies of energy in general, and electricity in particular, thereby diminishing dependence on any one source of supply and reducing the dependence on imported energy sources.[17] In particular circumstances, centrally generated electricity may offer unique economic advantages in comparison to other sources of energy generation, and after analysis, nuclear energy may emerge as the means for Cuba of producing energy at the lowest real cost.[18]

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satisfied most economically in terms of distribution as well as generation capacity. Answers to questions of how much, where and when will depend not only on the plotted incidence of demand, but also on the relative costs of generation and distribution. Some preliminary chart of size, location, and timing of desirable additions to the electric supply system is nevertheless an essential part of the preamble. See I. Smart, p. 25. See also Mudassar Imran and Philip Barnes, *Energy Demand in Developing Countries: Prospects for the Future, A World Bank Staff Commodity Working Paper, No. 23* (Washington: World Bank, 1990); International Energy Agency (IEA), *Energy in Developing Countries: A Sectoral Analysis* (Paris: OECD, IEA, 1994).

13 See Maarten Wolsink, "Dutch Wind Power Policy: Stagnating Implementation of Renewables," *Energy Policy* (Dec. 1996) Vol. 24, No. 12, pp. 1079-1088; Penny Street and Ian Miles, "Transition to Alternative Energy Supply Technologies: The Case of Wind Power," *Energy Policy* Vol. 24, No, 5 (May 1996), pp. 413-426; Thomas Drennen, Jon D. Erickson, and Duane Chapman, "Solar Power and Climate Change Policy in Developing Countries" *Energy Policy* Vol. 24, No. 1 (Jan. 1996), pp. 9-16.

14 See *Energy Efficiency and Conservation in the Developing World: The World Bank's Role–A World Bank Policy Paper* (Washington: World Bank, 1993).

15 For a discussion of the social implications of energy development in developing countries, see Goldemberg et al, pp. 9-57.

16 R. Thomas, pp. 2-3.

17 R. Thomas, pp. 2-3.

18 Much of the evidence in support of Thomas's analysis is now dated, and many of the factors that informed his conclusions have changed dramatically in the post-Cold War period. What remains

There is an underlying relationship between (a) a nation's energy needs and external dependence or exposure; (b) economic and political stability; and (c) broader security concerns. The intensity of these relationships of course, will vary from country to country in the developed and developing world, and within a country over time. When dealing with security in the context of energy, we are concerned with the broad and unavoidably subjective connotation of the term. Such a grand interpretation encompasses economic, political, strategic and military aspects of security, as opposed to the more minimalist interpretation that focuses on specific military threats and defense programs. Economic security focuses on national resource sufficiency and, in particular, access to goods and services in world markets in affordable terms. Political security suggests the maintenance of domestic stability, whether it is based on rule by the consent of the governed, or on varying degrees of authoritarian measures. Either way, law and order prevail, and economic, political and social activities are conducted with little or no hindrance. Strategic and military security is partly outward-looking and may be gauged by the degree and intensity of perceived external threats and the military capability that can be marshaled to meet those threats. It is also inward looking in that it involves the diversion of both domestic resources and services to meet those threats. The focus of this approach is on the effects of domestic energy shortages and external energy dependencies on the security and economic policies of industrializing or developing states. Issues confronting these states are analyzed under the dual context of crisis and post-crisis.[19]

It should be clear that a nation's energy policy and management carry significant implications for both its security and its economic domains. Energy shortages at home require adept diplomacy and adequate bargaining power to fill the breaches. External and internal security as well as external trade policies and economic development plans have their roots in the successful or unsuccessful management of energy policy. Energy policy management must maintain a satisfactory equilibrium or advance the policy to safer and more secure levels. Additionally, Thomas introduces three categories of developing states with nuclear energy programs. The first group consists of countries that were significantly impacted by higher oil import prices during the 1970s oil crisis and have subsequently embarked on nuclear energy programs. Their conversion to nuclear power capabilities raised the specter of nuclear proliferation in their respective regions. These countries

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significant about his analysis is that the notion of nuclear ambition in developing states remains a fluid concept. Since his book was published in 1990, South Africa, Argentina and Brazil have renounced their nuclear weapons programs. But in that same period of time, the proliferation concerns in the Persian Gulf region have been magnified, South Asia remains a region of significant proliferation concern, and the security of the vast nuclear stockpiles of the former Soviet republics is questionable and subject to diversion, smuggling and theft. For an analysis of the proliferation issue in the late 1990s, see Graham T. Allison, Steven E. Miller, Richard A. Falkenrath, Owen R. Cote, *Avoiding Nuclear Anarchy: Containing the Threat of Loose Russian Nuclear Weapons and Fissile Material* (Cambridge, MA: MIT Press, 1996).

19 Ibid. p. 9. Thomas looks at eight such states: South Korea, Taiwan, India, Pakistan, South Africa, Cuba, Brazil, and Argentina. They represent varying levels of economic development but are typified as middle-income or low-income countries. All were severely dependent on external sources of oil during the oil crises of the 1970s and have nuclear energy development programs at home.

India, South Korea and Taiwan are highly energy dependent; and they have promoted nuclear energy development. These states are also classified as high proliferation risks because of their respective external concerns. A second group, including South Africa and Pakistan, share similar attributes with those countries in the first group, but there are "far greater internal and external security pressures (in the latter group) and consequently greater temptations to acquire nuclear weapons.[20] This group is typified by the viability of the nuclear energy option to their national energy issues. But there are also questionable intentions of these programs because of the security consideration consequently their high propensity to acquire or develop nuclear weapons as demonstrated by the nuclear tests conducted in the spring of 1998. The third group of states has difficulty in obtaining oil because of cost and limited access, and there is an absence of major security concerns. The possible diversion of nuclear energy resources to a weapons capability has much to do with the satisfaction of national pride and international prestige. Argentina and Brazil are examples of states in this group. During the 1980s, the escalation of nuclear energy programs followed a spiral action-reaction phase of "one-ups-man-ship" that is characteristic of arms races and at the time suggested the possibility of a latent nuclear arms race between the two.[21]

Cuba did does not fit any of the categories presented but its inclusion in this discussion is significant because of a number of factors. The security concerns that Cuba's actions raise in the Western Hemisphere, especially in the United States are: the lingering Russian economic and technical influence in Cuba; the Cuban decision to embark on a nuclear energy development program; and Cuba's failure to ratify the Treaty of Tlatelolco. The use of Russian technology to set up the nuclear energy capability is a concern, as well as the transfer of Russian know-how may make it possible for diversion to a weapons capability in the future. Moreover, the suspect safety standards of Russian nuclear reactors lend credibility to the notion that a Chernobyl-like accident might occur, potentially threatening the greater Caribbean basin.

20 "The significant question is what defense or deterrent purpose a South African nuclear weapons program would serve even if the country were to divert its nuclear energy program in that direction.…Unlike, Pakistan, which faces the potential of a nuclear India…. the regime of South Africa need fear no such threat." Ibid., p. 10. For an excellent analysis of recent nuclear developments in South Asia, see Stephen P. Cohen, ed. *Nuclear Proliferation in South Asia: The Prospects for Arms Control* (Boulder, CO: Westview Press, 1991).

21 Ibid., p. 11. For an analysis of the Argentina-Brazilian case see John R. Redick..

The Limits of Economic Rationality

Implicit in most discussions of nuclear power choice is the assumption that national decisions to develop nuclear energy capabilities are based on careful consideration of the economic costs and benefits of nuclear power. Great attention in the debates over nuclear power, therefore, is toward such issues as the availability of alternative energy sources, future energy demand, the assurance of uranium supplies and the economic dividends from recycling plutonium. Moreover, the implicit understanding from such undertakings are that nuclear safety norms, adequate materials protection, control and accounting are all a part of that calculation.[22]

Nuclear power proponents cite the possibility of rising fluid fuels costs, rising energy demands and the potential loss of energy sources, the alleged lower costs of nuclear-generated electricity as reasons for pursuing nuclear energy capabilities. This is compared to alternative sources of power (based on estimates of high-capacity nuclear plant operation) and the economic necessity of nuclear power for energy-poor developing nations. These arguments in turn are countered with reference to the declining growth rate of global demand, the enormous capital costs of nuclear plants (relative to coal-fired facilities), the failure of nuclear plants to operate at expected output levels, the ample supply of fossil fuels for the foreseeable future, and the economic irrationality of nuclear power for developing countries which lack concentrated energy demands.

Although both schools tend to emphasize the role of economic rationality in the nuclear power decision-making process, it is likely that psychological and political considerations are just as important in national decisions to develop or expand nuclear power capabilities. This is particularly apparent with respect to developing countries.[23] More generally, those countries most attracted to nuclear power are frequently those for whom civilian nuclear programs are least promising economically.[24] A simple review of the requisite factors needed such as "technical and organizational infrastructure, grid size,

22 See Jonathan Benjamin-Alvarado, "The Quest for Power: A Cost-Benefit Analysis of Cuba's Nuclear Energy Policy," in *Cuba in Transition* Vol. 6 (Miami: ASCE, 1997), pp. 417-429.

23 Etel Solingen argues that in the case of designing civilian nuclear industries in Argentina and Brazil, focus should be concentrated on domestic political structures and institutions rather than on market structures, international regimes, the political power of private enterprises or ideology. Whereas most analyses in this area have been geo-strategically focused, Solingen investigates nuclear programs in the context of industrial policy. The development of an industrial capacity in designing a nuclear power reactor and its components does not invariably signal nefarious military objectives, although embracing such capability lowers technical barriers. A comprehensive nuclear energy program is not necessary if military applications are the leading objective because nuclear weapons can be obtained from a smaller dedicated program. Neither is the existence of a large-scale industrial program sufficient to impute strategic intentions to the state that develops it. See Solingen, *Industrial Policy, Technology, and International Bargaining: Designing Nuclear Industries in Argentina and Brazil* (Stanford, CA: Stanford University Press, 1996).

24 William C. Potter, *Nuclear Power and Nonproliferation*, p. 7.

generating unit size, and financing conditions tend to 'adversely affect the competitiveness of nuclear power, particularly in developing states."[25]

B. Nuclear Energy Development in Cuba

The Cuban program to develop nuclear energy has gained significance in the period since 1991. There exists a small but well-informed literature on Cuba's attempts to develop a nuclear energy capability. There also exists a body of literature devoted to the historical developments in Cuba's movement toward modernization, including the developments in economic dependency and technological ascendancy.[26]

Until the recent past, most of the research that centered on Cuba's nuclear program was government-produced policy and scientific and technical analyses.[27]Although these reports and analyses are seemingly exhaustive in their coverage, because of the conflictual nature of relations between the United States and Cuba, almost all of these analyses rely on secondary sources for information or have not been corroborated by independent analysis, and thus they remain open to debate and criticism. For many analysts, this is the key issue in the discussion related to nuclear safety in Cuba. Because of the on-going debate in the West over whether or not the reactors could operate safely there has also been a steady output of journalistic treatments of the subject.[28]

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25 Ibid, p. 8. Potter adds, "It is appropriate here simply to note that psychological factors can override strict economic analyses of the costs and benefits of nuclear power. Such factors are, for example, 'the need' to share advanced nuclear technology, the fear of missing the nuclear revolution, an unwillingness to accept a 'have not' status in an openly discriminatory nuclear world order, and in the case of the more economically advanced states, the desire to be a leader in the development of a new technology."

26 See, for example, Francisco Lopez Segrera, *Cuba.- capitalismo, dependiente y subdesarrollo (1510-1959)* (Havana: Casa de las Americas, 1972); Julia Feinsilver, *Healing the Masses.- Cuban Health Politics at Home and Abroad* (Berkeley: University of California Press, 1993); Susan Eva Eckstein, *Back to the Future:Cuba Under Castro* (Princeton, NJ: Princeton University Press, 1994) ; and Juan M. Del Aguila, *Cuba, Dilemmas of a Revolution* (Boulder, CO: Westview Press, 1994). Jorge I. Dominguez, *To Make the World Safe for Revolution: Cuba's Foreign Policy* (Cambridge, MA: Harvard University Press, 1989).

27 See GAO reports, Nuclear Safety: International Atomic Energy Agency's Nuclear Technical Assistancefor Cuba GAO/RCED-97-72 (March 1997); Nuclear Safety: Concerns With the Nuclear Power Reactors in Cuba GAO/RCED-95-236 (August 1, 1995); and GAO/RCED-92-262). See also Jerome L. Heffter and Barbara J.B. Stunder, "Transport and Dispersion for the Potential Accidental Release of Radioactive Pollutants From the Nuclear Reactor at Cienfuegos, Cuba. NOAA, Air Resources Laboratory (August 1992). For examples of similar reports from the Cuban government, see Dario Gandarias Cruz and Daniel Codorniu, El Programa Nuclear Cubano Y Su Infraestructura Cientifico-Tecnico, (1995) Agencia de Energia Nuclear, La Habana; and Miguel Serradet Acosta, Programa Nucleoenergetico Cubano, a paper presented at the Regional Seminar of Public Information, hosted by the Agencia de Energia Nuclear, La Habana, May 19, 1995. For an academic treatment of the possible environmental problems in Cuba see Barbaro Quintero-Leyva, A Preliminary Assessment of Nuclear Radiation Dose in the Case of a Hypothetical-Severe Accident Scenario Involving Breach of Containment at the Cuban VVER-440 (v2l3) Type Nuclear Reactor. Master's Thesis, Department of Nuclear Engineering, University of Florida, 1996.

28 For a recent example,see Frank J. Gaffney and Roger W. Robinson Jr. "Stop the 'Cuban Chernobyl'" *Wall Street Journal* (January 21, 1997), p. Al 9; Frank Gaffney, "'Useful Idiots': Why Would Any

Only a very few academic scholars have written specifically on the subject and there has been almost no application of social science theory to explain the wider influences and implications of this isolated and seemingly "unique" phenomenon. One of the earliest treatments on the issue was an article published by Jorge Perez-Lopez.[29] Perez-Lopez provided an assessment of the state of energy on the island but questioned the underlying rationale of the project for a country with significant resource constraints and the effects of the Chernobyl disaster on Cuban designs. Perez-Lopez argued that the effect of the Chernobyl nuclear accident would be marginal in arresting Cuba's nuclear ambition considering the country's poor energy base, deep economic and political commitment to nuclear energy and the absence of domestic opposition to nuclear technology.[30] Another study looked at the relationship between energy, security and economy in revolutionary Cuba in the latter stages of the Cold War. It concluded that while nuclear energy could contribute positively to the Cuban energy balance, it will not solve Cuba's energy vulnerability.[31]

The first comprehensive treatment on the scope and objectives of the Cuban nuclear project was written by Fidel Castro Diaz-Balart in 1986.[32] It was a thick tome, by the then-Director of the Cuban Nuclear Agency heavily descriptive of the structure and functions of the nuclear complex and the long-term scheme for the development of nuclear energy and nuclear science in Cuba. Its rich description and ambitious tone give an interesting account of the hope that the Cubans placed on the development of nuclear energy as one of the keys to economic development and modernization into the twenty-first century. It bears mentioning that the attempt to develop energy in Cuba has occupied the fascination of policy-makers on the island for well over 50 years.[33] In 1990, Castro Diaz-Balart published *Energia Nuclear y Desarrollo: Realidades y Desafios en Los Umbrales Del Siglo XXI.* The main proposition advanced in the book was a defense of the advantages of nuclear energy, arguing for the indispensable need for its assimilation.[34]

American Help Fidel Castro Bring His Cuban Chernobyl On-Line?" Center for Security Policy, Decision Brief No. 96-D 1 3 (February 10, 1996). See also, Juan 0. Tamayo, "Cuba Exagera Inversi6n Extranjera, Segun Perito (Cuba Exaggerates Foreign Investment According to Expert)." *El Nuevo Herald-Miami* (August 1 1, 1996), pp. 1 A, I 4A. The dissident press in Cuba has also contributed in bringing attention of the environmental ramifications of nuclear energy development on the island. For example, see Olance Nogueras Rofes, "Llevan Autoridades a Leonel Morejon Almagro Visitar Juragua" Buro de la Prensa Independente Cubano (BPIC) distributed on the Internet via cubanet.org, (March 26, 1997).

29 Jorge Perez-Lopez, "Nuclear Power in Cuba After Chernobyl," *Journal of Interamerican Studies and World Affairs.* (Summer 1987) pp. 79-117. See also Jorge Perez-Lopez, "Nuclear Power in Cuba: Opportunities and Challenges," *Orbis* 26, no.2 (Summer 1982).

30 Ibid., p. 79.

31 Jorge Perez-Lopez, "Cuba" in *Energy & Security in the Industrializing World,* Raju G.C. Thomas and Bennett Ramberg, eds. (Lexington: University of Kentucky Press, 1990), pp. 153-181.

32 Fidel Castro Diaz-Balart, *La Energia Nuclear en La Economia Nacional de La Republica de Cuba* (Moscow: COMECON, 1986).

33 See Foreign Policy Association, Commission on Cuban Affairs, "Chapter XVII: Public Utilities," in *Problems of a New Cuba.* (New York: Foreign Policy Association, 1935), pp. 397-442.

34 Fidel Castro Diaz-Balart, *Energia Nuclear y Desarrollo: Realidades y Desaflos en los Umbrales del Siglo XXI.* (La Habana: Editorial de Ciencias Sociales, 1990).

Another Cuban associated with the nuclear program also authored another interesting addition to the literature on Cuba's nuclear activities. As a defector in 1992, Jose R. Oro, a geologist, arrived in the United States under much hoopla over his revelations of "new" developments in Cuba's nuclear program, including allegations of a more nefarious rationale, the development of weapons of mass destruction. He subsequently authored *The Poisoning of Paradise.* His book argues that the Cubans were disregarding standards and norms associated with the safe construction, and the operation of a nuclear reactor, and environmental considerations were being disregarded because of a lack of adequate economic and material resources required for the construction of the nuclear reactor. Oro warned that Cuba's use of nuclear power posed a clear and present danger to the environment in Cuba and beyond. Although his book makes many claims, Oro cites so little supporting evidence that a reader cannot be certain that the information is objective or reliable.[35] These two previous examples fall prey to the same doubts expressed in relation to the reports generated by the respective governments, that they rely on secondary sources for information or that they cannot be independently verified or refuted.

Another source of information on the Cuban nuclear program is the proceedings of two sets of Congressional hearings which were conducted to investigate the claims of a potential nuclear accident in Cuba.[36] These high-profile, highly partisan hearings garnered much media coverage and have been instrumental in placing the nuclear issue near the top of United States interests in relation to Cuba.

To date, other analysts have provided a number of articles analyzing Cuban nuclear energy policy, nonproliferation and the structure and functions of the those activities in Cuba.[37] These articles have sought to provide a background for conducting research that is theoretical in nature and rigorous in methodology. Such a background has served the policy community well and is recognized as an important contribution to our understanding of the multiple debates surrounding the Cuban nuclear program. Other such examples are the works of Maria Dolores Espino, Sergio Diaz-Briquets and Jorge Perez-

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35 See Jose R. Oro, "Part Two: The Cuban Nuclear Program and Its Ecological Impact," in *The Poisoning of Paradise: Environmental Pollution in the Republic of Cuba* (Miami: The Endowment for Cuban American Studies, 1992), pp. 15-39.

36 In separate instances congressional hearings have been convened to provide information on the safety of the nuclear reactors under construction at Cienfuegos. See the proceedings of the 1991 hearing, "International Commercial Reactor Safety" by the Subcommittee on Nuclear Regulation of the House Committee on the Environment and Public Works, July 25, 1991; and the proceedings from the 1995 hearings, "Nuclear Safety: Concerns with the Nuclear Power Reactors in Cuba" by the Subcommittee on the Western Hemisphere, House Committee on International Relations, August 1, 1995.

37 See Jonathan Benjamin-Alvarado and Alexander Belkin "The Cuban Nuclear Program and Post-Cold War Pressures" *The Nonproliferation Review* 1:2 (Winter 1994) pp. 18-26; Jonathan Benjamin-Alvarado "Proliferation Risks and Nonproliferation Opportunities in Cuba: An Assessment of Nuclear, Biological and Chemical Weapons Capabilities" *The Military and Transition in Cuba: A Reference Guide for Policy and Crisis Management* (Washington: International Research 2000, 1995) Sec. 111.2, pp. 1-8; "The Quest for Power: A Cost-Benefit Analysis of Cuba's Nuclear Energy Policy" *Cuba in Transition,* Volume 6 (Miami: ASCE, 1997) pp.417-429; and *Washington and the Cuban Nuclear Imbroglio.* An International Policy Report, No. 17, (Washington: Center for International Policy, February 1998).

Lopez. They analyze the nuclear program within the context of modernization and development and its relation to the environmental implications for Cuba and the greater Caribbean.[38]

The preceding section was a discussion of the role of energy development in modernizing and developing states, including the basis for analyzing decision-making processes, the economic considerations for energy development, and the relationship between energy development, economic and political considerations in developing states. It also provided many of the indicators needed in the subsequent analysis of the Cuban nuclear program. States develop nuclear energy capabilities under a number of different circumstances and for a number of different reasons. While it could be argued that the issue is one of the relationship between nuclear power and economic development in general, the preponderance of the discussion in this section centered upon identifying the criteria by which developing states may determine whether the exploitation of nuclear fission represents a rational option for them. The introduction of nuclear power may help to diversify and augment the domestic supplies of energy in general and electricity in particular, thereby diminishing the dependence on any one source of supply and reducing the dependence on imported energy sources. Understanding the relationship between energy, a state's economy and its security posture can lead to understanding its objectives and eventually its actions in the government's effort to provide secure and reliable sources of energy for its society. This section concluded with a caveat about the limits of economic rationality, especially for developing states in their pursuit of nuclear energy capabilities where psychological and political considerations may supercede economic ones in those considerations.The final section of the review explores the case specific literature on nuclear energy and energy development in Cuba. It included a discussion of Cuban sources which heretofore have not been included in the existing literature and which promise to expand our knowledge base and understanding of specific activities related to the development of nuclear energy capability in Cuba.

III. Nuclear Energy Program Objectives

At the start of the nuclear development program in Cuba the government emphasized the economic benefits. Fidel Castro Diaz-Balart, the former Executive Secretary of the Cuban Atomic Energy Commission (CEAC) and son of Fidel Castro, claimed that the first reactor, when running at full capacity, would allow the country to conserve 600,000 tons of oil annually.[39] The one reactor would lessen Cuba's dependency

38 Maria Dolores Espino clearly elucidates the reasons for concern over environmental deterioration in Cuba. Among the reasons listed are production maximization without consideration of costs, an inadequate regulatory environment and the absence of pressure groups. Additionally, Cuba suffers from many of the same factors that also affect "developing" countries, such as: chronic external trade imbalances and debt burdens; the use of inefficient, inappropriate and obsolete technologies; and a lack of adequate financing for infrastructure. In Espino, "Environmental Deterioration and Protection in Socialist Cuba." in *Cuba in Transition - Volume 2.* (Washington: ASCE, 1992); see also Sergio Diaz-Briquets and Jorge Perez-Lopez, "Water, Development, and Environment in Cuba: A First Look," in *Cuba in Transition- Volume 5* (Washington: Association for the Study of the Cuban Economy, 1995).

39 Fidel Castro Diaz-Balart, *La Energia Nuclear En La Economia Nacional De La Republica de Cuba*

on imported oil, thereby developing a stronger bargaining position with the Soviets and somewhat diminish the impact of the U.S. embargo. Throughout the 1980s, Cuba's domestic oil production was roughly between 1 and 1.5 million tons annually. The amount required to meet its basic energy needs is 8 million tons annually.[40] Under its trade arrangement with the Soviet Union, Cuba received up to 12 million tons annually.[41] The arrangement allowed Cuba to re-sell the excess and to export high-grade oil at world market prices in order to earn much-needed hard currency. During the "Special Period," Cuba has been able to generate only between 30 to 50 percent of the energy required to fuel the economy. The severely diminished output has resulted in nightly blackouts, limited telephone service, and extensive shutdowns of factories and industrial projects throughout the island. The peak energy use on the island is 1,300 to 1,500 MW per hour, and the addition of a 440 MW reactor would only partially reduce the impact of the loss of Russian oil imports.[42]

In fact, in the ten-year period from 1985 to 1995, the actual production of electricity fell 9 percent. More dramatic was the drop of over 36 percent from the 1990 peak year of electricity production. In this period the need of a secure source of energy became painfully obvious to the Cubans. The loss of favorable trade arrangements with the Soviet Union compounded the stagnant growth of the late 1980s, and between 1990 and 1993 Cuba's economy shrank by almost25 percent. There were certainly other mitigating factors to explain the dramatic drop, but the drop in electricity production must be counted among the most important ones.

Table 1 Cuba's Sources of Energy – 1995

Type of Generation	*Potential Megawatts (MW)*	*Percentage*
Thermoelectric	2,983.5	80.3
Hydroelectric	48.6	1.3
Gas Turbine	100.0	2.7
Sub-total	3,132.1	84.3
Industrial Plants	584.4	15.7
TOTAL	3,716.5	100.0

Source: Miguel Serradet Acosta, "Programa Nucleoenergetico Cubano," a paper presented at the Regional Seminar on Public Information, Havana, Cuba, May 19, 1995, p. 3.

(Moscow: COMECON, 1986), p. 9. Castro Diaz–Balart adds ambiguously that " if all four units were operating the savings would be 2.4 annually." He may have been referring to two more units in addition to the Units 1 and 2 at Juragua but his reference is unclear.

40 Interview by author with Arnaldo Coro Antich, Chief Science and Technology correspondent, Radio Habana, Havana, Cuba (June 6, 1993).

41 During the 1980s, Cuba consumed on average 10.83 million tons of oil. For the 1990s the figure dropped 8.7 percent to 9.88 million tons annually. See *Energy Statistics and Balances of Non-OECD Countries, 1994-1995,* pp. 142-143.

42 Ibid.

Overall, the expansion of Cuba's energy sector has been impressive. This has resulted in the construction of thermoelectric facilities, the modernization of existing facilities, the installation of hundreds of kilometers of electrical power lines, and the placement of hundreds of sub-stations as a part of a single interconnected 110kV and 220 kV network which was brought into line with the national electrical energy system. In 1988 the Total Gross Production of electricity was 1450kW/h per capita–more than 3 times the amount being generated in 1958. By 1995, this figure had been reduced to 1110kW/h.[43]

Energy Intensity and Energy Efficiency

There are also less tangible, measurable and predictable costs that may have to be considered. One of these is the impact of current rates of energy consumption on the environment. For example, in the period 1980-1983 (when Cuba first seriously considered the actual construction of nuclear energy reactors) the GDP grew 6.75 percent per annum and energy consumption grew by over 4.9 percent per annum. The energy intensity was negative 1.85 annually. This is an indicator that the growth of the GDP during period was sufficient to cover the growth of energy consumption in Cuba during that same time period resulting in negative energy intensity. Although Cuba may have considered the need to develop its energy sector, it was most likely not needed considering its rates of growth and consumption. Moreover, if we consider the potential for environmental degradation due to increased rates of energy consumption, the situation in the early 1980's was one where Cuba was making efficient use of its energy resources. The impact of the post-Cold War period has been significant as far as Cuba's energy intensity was concerned. For the period 1992-1995, Cuba's GDP fell 6.3 percent annually and energy consumption decreased 3.07 percent annually before the energy intensity was a negative 9.3 annually over that time period.

The evolution of energy intensity over time reflects the combined effects of structural changes in the economy as well as changes in the mix of energy sources and efficiency in energy use. Although it is a very rough indicator, energy intensity has some attractive features. While energy consumption and *GDP* per capita vary by more than one order of magnitude as the analysis goes from developing to developed countries, energy intensity does not change by a factor of more than 2, indicating that there are important commonalties among the energy systems of rather different countries. As far as developing states are concerned, this change in intensity probably reflects the fact that the "modern sector" of the economy dominates both energy consumption and *GDP* and the "traditional" sector contributes little to either.[44] It also refutes the notion that development requires a major increase in energy use per capita. For developing countries, advancement in the energy sector means purchasing technologies and resources not available at home for modernization, industrialization and debt reduction. Thus, paying for imported oil comes to be seen as a financial hemorrhage of the developing world. Debt crisis emerges,

43 Castro Diaz-Balart, p. 346.
44 Ibid.

and the economic growth of developing states stalls.[45] The energy intensity also has implications for the satisfaction of basic needs and the quality of life.[46]

In the case of Cuba, it becomes very apparent that the wild rates of growth and decline for these variables reflect manageable energy consumption in the 1980-83 period and the drastic shortage of energy in the 1992-95 period. If the application of the nuclear option to address this potentially grave situation provides a solution to this dilemma or could ostensibly strengthen Cuba's energy supply, it is still unclear. In the latter period, the crippled energy sector was forced to rely on "traditional" forms of economic activity to a point where animal and human labor comprised the most secure form of "energy" for the island. A positive benefit of this otherwise dismal situation was the dramatic reduction in emissions and pollution throughout the island. Even as the country has began to reverse the trend toward negative growth with a modest recovery in the past three years, Cuba is still facing chronic energy shortages and inefficiencies that could limit this recovery in the long term.

Recently, Cuba has initiated measures on the home front to deal with these nagging problems. To deal with the lack of new energy sources coming on line, the government is considering a number of measures aimed at encouraging conservation. The most draconian would be requiring all business, including state-owned enterprises, to pay their electric bills in hard currency. The aim would be to try to make sure that the 66 percent of power demand from industry is paid for in hard currency since much of the island's power is generated using imported fuel oil, which must be paid for in dollars. These measures would be a strong incentive for companies to conserve energy as many have little or no access to large hard currency reserves.[47] On February 4, 1998, Ricardo Gonzalez, executive director of Cuba's national energy conservation program, announced that the program was being extended nationwide. It previously pertained to commercial enterprises. He stated,

> The example that has been used is that by reducing consumption by 1 MW during peak hours could translate into savings of $1 million in investments. The goal we have set for this program is to reduce consumption by at least 150MW that could represent savings of $150 million in investments. In three years, this could achieve savings of $37 million in fuel purchases as a result of the implementation of these measures.[48]

45 Jose Goldemberg, Thomas B. Johansson, Amulya K.N. Reddy, Robert H. Williams. *Energy for Development* (Washington: World Policy Institute, 1987), p. 1.

46 This will be discussed in the cost benefit section of this chapter.

47 "Foreign Capital to Fund Expansion of Cuban Capacity," *Latin American Power Watch* via Lexis-Nexis (February 1, 1998).

48 "Energy Conservation Programme Extended Nationwide," Radio Rebelde, Havana, Cuba (February 5, 1998) transcript via BBC Summary of World Broadcasts, February 17, 1998.

These measures would consist of introducing of energy-efficient light bulbs, refrigerator gaskets, etc. Cuban officials publicly state that habits of energy consumption must change for all of Cuba, including the state.[49]

Sectoral Energy Demand

An important precursor to the development or expansion of the energy sector is the assessment the sectoral demand structure and consumption trends. For the purposes of this examination the assessment will consist of three separate snapshots of domestic energy consumption taken in 1972, 1982 and 1995. In the period between 1972 and 1995, Cuba's total domestic consumption increased by 48.7 percent.

The proportion dedicated to the energy sector decreased from a total 12.1 percent to only 7.4 percent of total consumption. The industrial and residential sectors remained fairly stable with the consumption increasing 3.8 percent and 2.4 percent respectively. Interestingly, in the 23 year period of this assessment, the residential and industrial sectors both increased the total electricity consumption by over 44 percent (44.3 and 44.9% respectively). In the thirteen-year period between 1982 and 1995, total consumption actually decreased by 3.1 percent. The decline resulted, in part, from the dramatic loss of oil from the former Soviet Union but it also points to a more efficient cycle of production and consumption in Cuba.

Scale and Location

Originally the Cuban–Soviet agreement to develop nuclear energy called for a network of 12 nuclear reactors across the island increasing Cuba's energy generation potential by 4,800 MW. By the mid-1980s this ambition had been curtailed somewhat by Cuba's resource and technological constraints. In 1986, the plans were re-adjusted to call for 3 facilities with two 440MW units each to be installed in Cienfuegos, Holguin and Occidente provinces. The new plan would increase Cuba's generating capacity by 2,640 MW (71 percent) to almost 6400MW, comprising 41.5 percent of Cuba's total energy generating capacity. In 1991, the Cuban government placed all other plans for the nuclear program in a "state of suspension" when the Russians withdrew funding for the construction at Juragua and all other nuclear related activities in Cuba. In assessing the state of energy in Cuba, the analysis of the resource constraints and intensities confronting the Cuban energy development program clearly provide support for the economic and technological modernization. Specifically, Cuba's efforts to manage consumption, promote conservation and monitor demand were effective and focused on the long-term economic benefits as opposed to any politically expedient rationale. This may have been because Cuba had no other choice faced with the loss of Soviet sources for fossil fuels, but Cuba's response to these factors were measured in terms consistent with economic and technological modernization. The development of the stand-alone nuclear energy capability would limit Cuba's exposure to external dependency for energy, but there is

49 "Need for Energy Savings Stressed at Basic Industry Meeting," Cuba Vision, Havana, Cuba (February 9, 1998) transcript via BBC Summary of World Broadcasts, February 24, 1998.

little to suggest that this was the focus of the activities in this area. Moreover, one could argue that the development scheme to achieve a nuclear capability was in reality, merely an exchange of one type of dependency for another, albeit more highly advanced. There was little or no mention of the nationalist or ideological imperatives in which official government policy is often cast in Cuba.

IV. Policy Results and Implications

The evaluation of the Cuban nuclear program is based upon both quantitative and qualitative indicators. As presented in the first part of this paper, the quantitative variables are investment capital, external dependence, supply inflexibility, institutional gravity and energy intensity. The qualitative variables are a discussion of the domestic policy context and international circumstances, as well as the specific developments in the scientific and technological arena in Cuba. With these elements discussed we can then embark on an appraisal of the national energy development strategy, and the social and economic implications of that strategy.

- We begin this evaluation with the Cuba's ability to attract investment capital for its nuclear energy development program. For Cuba's energy development program the 1990s can be viewed as a lost decade. With the loss of assistance from the Soviet Union, Cuba's nuclear ambition has diminished appreciably. Since 1992, Cuba has attempted to fill this void by attracting investors willing and able to commit nearly $1 billion to complete the reactors under construction at Juragua. Under the present circumstances To this point, Cuba has only received around $30 million to mothball the facility. It is clear that Cuba could have devoted the $1 billion already spent on the project to other available forms of energy generation. This is amplified by the renewed interest from a number of international firms in Cuba's energy sector since Fidel Castro's 1997 announcement to pursue other energy alternatives. In 1998 alone international firms have "committed" over $500 million to construct or modernize thermoelectric facilities.[50]

- Regarding the external dependence of Cuba's energy supply, the evidence presented strongly suggests that while Cuba sought to and continues to seek the means of reducing that dependency. Yet it is also apparent that two factors have effectively mitigated the potential reduction of Cuba's dependency on imported oil. First, Cuba's over-reliance on Russia as a sole source of expertise, materials and financing for the program effectively rendered the program moribund when the Russians could no longer provide assistance to the Cubans. This also had the unintended impact of casting suspicion on the integrity of the Soviet design and construction of the facility, especially in the wake of the Chernobyl disaster and other nuclear accidents in the former Soviet Union. Second, the recent interest in the thermoelectric generation facilities while eventually increasing Cuba's generating capacity will also engender a

50 See Jonathan Benjamin-Alvarado, "Investment and International Cooperation in Cuba's Energy Sector." Paper presented at the 8th Annual Meeting of the Association for the Study of the Cuban Economy, Miami, FL (August 6-8, 1998).

greater dependence upon imported oil for Cuba. This may be of little concern while world oil prices remain low, but as prices rise the impact on Cuba's energy sector would be significant.

- The addition of the Juragua Unit No. 1 to Cuba's electricity grid would only partially reduce the loss of imported oil that Cuba is presently enduring. In fact, as Cuba's energy demand continues to grow the impact of the addition of nuclear energy would diminish over time. The reliance on imported fuel for over 80 percent of Cuba's energy places the energy sector in an over-exposed posture. Adding more thermoelectric facilities to the grid will aggravate this over exposure. Cuba will have to carefully consider how it intends to address this chronic problem area. Given this consideration the addition of nuclear energy capabilities remains a viable alternative to the inflexibility of over-dependence upon oil.

- Cuba has devoted a significant portion of the island's top scientific, technical and administrative talent into the highly centralized institutional structure of the energy sector. This has resulted in the development of a well-trained yet highly under-utilized cadre of nuclear engineers, technicians and administrators. This has also given rise to a highly developed and integrated scientific and technological education and training system. Cuba's energy bureaucratic structure is still evolving with hopes of meeting the threshold of international standards and norms in the nuclear field. The trajectory of policy implementation is consistent with the Cuban government's overall objective of integrating the benefits of advanced science and technology into the fabric of everyday Cuban life through research and application.

- Evaluating Cuba's energy intensity does not provide a clear indication of the present situation because of the wild fluctuations in GNP growth and energy consumption figures for the 1990s. As a result of these fluctuations Cuba has experienced lower emission of pollutants as the rates of energy consumption has fallen dramatically because of a shortage of oil supplies as opposed to more efficient consumption rates. This does not mean though that Cuba can viewed as a paragon of environmental efficiency as many standard practices remain well outside standard pollution control standards mostly because of a lack of resources.

- The relationship between Cuba's domestic energy policy objectives has been effected most in the post-Cold War period by the loss of assistance from the Soviet Union. In fact, this is the first time in the 500-year period since the discovery of Cuba by Christopher Columbus, that the island has been completely isolated and self-reliant. This is not to minimize Cuba's efforts to expand trade with other nations, but it is the first time that Cuba has partaken in international trade and commerce without a strategic and economic guarantor, such as Spain, the United States or the Soviet Union in place. Whereas Cuba has previously been the beneficiary of pleasant conjunctures of history and coincidence, in this instance, the circumstances have been especially difficult for the government of Cuba. Two areas of Cuban life and society

have been especially debilitated by these circumstances. Those areas being national energy development and energy consumption.

- Cuban nuclear ambitions notwithstanding, the expansion of electricity to the furthest reaches of the Caribbean's largest island is admirable. But we should not minimize the fact that the expansion was possible because of the existing energy grid already in place. The socialist regime has extended this capacity to parts of the island previously untouched. The addition of the nuclear option for Cuba was a logical decision under the conditions of the Cold War and by virtue of its close relationship with the Soviets. It is far too easy to focus of the unanticipated demise of the Soviet Union as the *explanadum* for Cuba's present energy woes. Even in an area of development where the logic of economic rationality has its limits, Cuba's attempt to exploit the nuclear option was consistent with social, economic and technological imperatives facing Cuba, and was a realistic solution given the circumstances under which the decision was undertaken.

- The down side of Cuba's dedication to pursuing the nuclear energy capability was its indirect neglect of the supporting energy infrastructure. This is not to argue that Cuba did not conscientiously attempt maintain the infrastructure. But one must be cognizant that the present infrastructure is about 50 to 60 years old. Often equipment and replacement parts from the Soviet Union were incompatible with the American built systems but the Cubans made the systems work. With the closing of the 1990s, Cuba must now begin to replace much of that infrastructure. Investment in this area of the energy sector will dwarf any of the figures presently being discussed for the construction of energy generation facilities. At a minimum the investment will total in the billions and will in all likelihood take 20 to 30 years without interruption. This task is lining up as one of the most daunting for the Cubans in the next century.

- The social impact of Cuba's attempt to develop a nuclear energy capability has had mixed results. On the one hand Cuba has bolstered the scientific and technological base through an assiduous pursuit of this capability, while on the other Cuba is really no closer to solving its chronic energy problems than it was at the beginning of the nuclear program. Many of these highly trained personnel have been forced to find employment outside of the energy sector. Some critics of the program argue that Cuba would have been better served by simply expanding its thermoelectric capacity rather than devoting the over one billion dollars and 15 years spent pursuing its nuclear ambition. Be that as it may Cuba chose the more costly and now seemingly fruitless option. The impact to Cuban daily life has been crippling. Entire portions of the island endure periodic losses of power and the disruptions severely constrain Cuba's ability to push its economy along. The recent interest in the thermoelectric sector, while promising in the short-term, does little to enhance Cuba's ability to provide reliable sources of power for the residential and consumer sectors in Cuba. Moreover, as previously detailed, it increases Cuba's dependence on imported fossil fuels and further subjects the evolving Cuban economy to the vagaries of world markets. This is

potentially devastating to an economy forced to operate without out much of a safety net.

U.S. Interests in Perspective

Since the breakup of the Soviet Union, concern regarding the program has taken a position of some significance among the issues that make up the United States' foreign policy toward Cuba. Several recent pieces of legislation have been directed at promoting a transition to democratic governance in Cuba: the Cuban Democracy Act of 1992 (The Torricelli Act), the Cuban Democratic Solidarity and Liberty Acts of 1996 (The Helms-Burton Act or Cuban *Libertad* Act), and the 1997 International Atomic Energy Agency (IAEA) Accountability and Safety Act (H.R. II 82). All contain provisions directed at blocking third parties including the Russian Federation from funding and constructing the nuclear reactors at Juragua.[51]

Prominently displayed in the Helms-Burton Act of 1996 are provisions that set out to limit Cuba's ability to complete its nuclear policy objectives of completing construction of the nuclear reactors at Juragua. Specifically, these provisions aim to reduce the desire of Cuba's would-be nuclear trading partners, most notably the Russian Federation, from engaging the Cubans in any meaningful way. This law calls for the "withholding of assistance allocated for any country an amount equal to the sum of assistance or credits . . . in support of the completion of the Cuban nuclear facility at Juragua" (Title 1, Sec.111).

One could argue that the mostly symbolic nature of Cuban-Russian nuclear cooperation in the post-Cold War period is indicative of the success of the U.S. policy. A much more reasonable appraisal would point to the chronic shortages of hard currency for both partners that have brought this project to a standstill. Yet, these provisions aim to limit the possibilities of this cooperation with the threat of a reduction in foreign aid to the Russians. Ironically enough, this law contains exemptions for the most significant area of assistance effecting Russia's nuclear industry. Under the 1993 Comprehensive Threat Reduction Act or "Nunn-Lugar Act" (Public Law 103-160), Russia's nuclear infrastructure has been earmarked to receive assistance to stabilize its nuclear assets. Moreover, assistance to Russia and other states of the former Soviet Union are exempted from these sanctions in the areas of political, economic and humanitarian aid. This has the effect of allowing Russia's Minatom a free hand to continue cooperating with Cuba and pursue reactor sales in the international nuclear markets. Furthermore, under the provisions of international nuclear accords and as a member of the IAEA, Cuba is entitled to pursue a nuclear energy capability so long as it adheres to provisions of full safeguards and nuclear safety protocols.

Since the 1980s, Cuba has been a very active member of the IAEA. During the 1980's Cuba held a seat on the Agency's Board of Governors and Cubans have served as

51 See Konstantin Zhukovsky, "Cuban Foreign Trade Minister to discuss cooperation matters," *ITAR-TASS* (June 2, 1997); and Veronika Romanenkova, "Russia may construct nuke plant in Cuba in 1998), *ITAR-TASS*, (June 5, 1997).

international safeguards inspectors. The IAEA has provided a number of Cubans with advanced training in the areas of safety assessments, designing and implementing training programs for personnel involved in the operational safety and maintenance of nuclear installations, and projects to assist in licensing the reactor and providing quality assurance for them. It has also sponsored regional informational seminars in Cuba for the exchange of information on applications of nuclear energy. Most recently, Cuba hosted an IAEA co-sponsored International Symposium on Nuclear Related Technologies in Agriculture, The Environment, and Radiochemistry in Havana in late October 1997. Over 31 nations and were represented with 450 scientists, technicians and nuclear engineers participating. This can be viewed as a complimentary function to the wider international norms and standards related to the peaceful exploitation of nuclear energy. Additionally, there is a strong linkage between Cuban and Soviet/Russian nuclear scientists and engineers. This consists of a sort of "nuclear brotherhood" of a cadre of specialists who were educated and trained under the old Soviet system. Few can argue with the quality of this process and it attests to the Cuban claims of technical competence.

In February 1997, *NBC Nightly News* reported that funds contributed by the United States to the organization were being used to fund training programs for the nuclear program in Cuba. A subsequent GAO study of the issue indicated that indeed that a portion of the voluntary contribution by the United States was earmarked for technical assistance programs for the Cubans.[52] But a closer inspection of the figures behind this "news story" indicates that there is more smoke than substance in relation to this issue. In 1996, the United States contributed $16 million (about 30 percent) of the technical cooperation fund. Cuba for its part contributed $45,150 (or 0.7 percent) to this fund. The IAEA has approved $1.7 million in technical assistance for projects for Cuba for 1997 through 1999. By extrapolation the United States contribution to the fund over this same period of time would be around $48 million of the $159 million total. The amount of technical assistance for Cuba $1.7 million is 3.5 percent of the total US contribution. That assistance from the IAEA coffers to Cuba represents 1.06 percent of the total contributions of the fund for 1997 through 1999. The reduction of the 3.5 percent proportion that goes to Cuba from the US contribution to the fund would only amount to a paltry $59,500. This would hardly disable Cuban cooperation with the IAEA, nor could it be conceived as an impediment to the provision of assistance to Cuba from the agency. Symbolically, opponents of the Cuban program could point to the non-involvement of the US for assistance programs from the IAEA. Whether it is $59,500 or $1.7 million matters little. The IAEA will most likely push forward with the assistance and training programs that ultimately benefits the United States as well as Cuba.

Yet in July 1997 a bill was introduced in the House of Representatives by Congressman Robert Menendez to withhold US assistance for programs and projects of the IAEA in Cuba. H.R. 2092, known as the IAEA Accountability and Safety Act of 1997, is clearly designed to wash American hands clean of any involvement in Cuba's nuclear program. A similarly worded amendment was included in the 1997 Foreign Relations Authorization Act for 1998 and 1999. But short of painting a self-

52 See *International Atomic Energy Agency's Nuclear Technical Assistance for Cuba* (GAO/RCED-97-72) March 1997.

congratulatory and triumphalist picture of uncompromising opposition to the Castro regime these bills are essentially toothless and clawless tigers and would violate the spirit of international nonproliferation cooperation. Like the Helms-Burton law these proposed pieces of legislation, renders them moot by the nature of the exceptions to their provisions. Sec. 2 (2)(B)(I) states that the law would not apply to IAEA programs for "safety inspection of nuclear facilities or related materials, or for inspections and similar activities designed to prevent the development of nuclear weapons" by Cuba. This sounds very much like the mission of the international organization under which all these activities would take place.

The restrictions specific to the Juragua facility and the nuclear research center at Pedro Pi would be lifted by the United States if Cuba: (a) ratifies the Treaty of Tlatelolco or the Nuclear Nonproliferation Treaty; (b) negotiate full-scope safeguards with the IAEA not later than two years after ratification of the accord; and (3) incorporates internationally accepted nuclear safety standard into practice. Interestingly enough this has been the focus of Cuba's nuclear activities for well over the past 2 years. In 1996, the Cubans embarked on a new nuclear law project to compliment the passage of *Decreto-Ley No. 208 - Regarding the National System of Accounting and Control of Nuclear Materials*. Cuban nuclear officials have indicated that the reason for delay in the ratification stems from the need to alter the existing legal basis of nuclear law so that it will more easily comply with the provisions of agreements with which they fully intend to comply with. *Decreto-Ley No. 208* represents part of that effort. Cuban nuclear officials are clearly cognizant of the shortcomings of the Soviet-based systems of accounting, control and materials handling. They have sought to design legislation that conforms to internationally recognized standards and norms of nuclear materials handling and storage. They have modeled the system in spirit to the scope and objectives contained in US Nuclear Regulatory Commission standards. Reaching that standard is another question altogether. But they have sought to make this system amenable to the requirements of the full-scope safeguards agreements that Cuba intends to sign when the treaty comes into force. On a larger scale the new nuclear law project, under the direction of the *Agencia de Energia Nuclear* and the *Centro Nacional de Seguridad Nuclear*, seeks to place all of Cuba's nuclear activities under a system of laws and practices that correspond to existing and future international nuclear standards.[53] Should this come to pass, and by all indications, it appears that it will. There will be very little that the United States can do to impede the progress of the Cuban nuclear project.

The development of a nuclear energy capability should be, and is a legitimate concern of U.S. officials but this does not imply that the Cuban program poses an imminent threat to the United States. A nuclear accident would certainly impact the Caribbean Basin but we should put to rest the notion that Juragua is a national security threat. This is so for the following reasons. First, Cuba is not presently in possession of nuclear fuel. Under the terms of its nuclear cooperation agreement with the Russian Federation, Cuba is to receive its nuclear fuel from the Russian Federation, and Russia

53 Jonathan Benjamin-Alvarado, "The Cuban New Nuclear Law Project" *The Monitor: Nonproliferation, Demilitarization and Arms Control*. Vol. 3, No. 3 (Summer 1997), p. 41.

originally agreed to take back all nuclear waste from the operation of the nuclear reactors at Juragua. At this moment, Russia does not have the capability to deliver the nuclear fuel to Cuba. Nor is it certain that the Russians would now be willing to take back the nuclear waste. Second, if Cuba were to hypothetically become creditworthy overnight or find a willing financier, the soonest we could expect construction of the reactors to be completed would be early 2002. This would be barring any significant delays in construction for backfitting or replacement of parts. It almost goes without saying that it will be a necessary condition for the project to move forward that welding and components will have to be replaced. A more conservative and realistic prediction for the completion of the nuclear reactor would be closer to 2003 or 2004, if ever at all.

The present policy is aimed at limiting international cooperation with a mostly moribund nuclear energy development program. Some of the provisions codified in U.S. law violate the spirit of international nonproliferation cooperation for mostly symbolic considerations of domestic politics. Moreover, this posture has had a spillover effect into the domestic arena where now we are constructing radiation detection networks for "national security" threats that does not and will probably never exist.

V. Conclusion: Cuban Energy Development in the Next Century

In conclusion this analysis has set out to definitively assess the impact of Cuba's attempt to develop a nuclear energy capability in terms relevant to Cuba and its society. Moreover, the focal objectives of the program, energy economics, energy security and economic and technological modernization ultimately serve as the determinants of a state's decision to pursue such a policy. First, the exploitation and addition of a nuclear energy capability to the centrally generated electrical grid would offer economic advantages, and while initially costly, nuclear power had the potential for emerging as the lowest real cost alternative for Cuba. Second, The introduction of nuclear power, once on line would have helped Cuba to diversify its supplies of energy thereby reducing its dependence on imported oil. Finally, the nuclear program was instrumental in raising Cuba's level of scientific and technical development in a number of sectors. Because of Cuba's reversal of fortunes since the ending of the Cold War none of these objectives have come to fruition. It leaves the Cuban energy sector with few options. There have been limited investment opportunities in the thermoelectric sector, but none of the $800 million estimated investment needed to complete the Juragua project.

One might be able to argue rather persuasively that the Castro-less Cuba, the 21st Century Cuba will have significant energy issues. This paper has asserted that energy development has been and remains, as one of Cuba's most daunting public policy issues. Regardless of whether or not Cuba selects the nuclear issue, any hope for economic revitalization will depend on Cuba's ability to provide the island with a reliable energy infrastructure. Moreover, Cuba's present reliance on oil exports does little to insure its development against a possible disruption in oil supply. One can further argue that the survivability of the post-Castro regime is contingent upon its ability to meet the basic needs of the Cuban society. Obviously, electricity ranks among these basic requirements. This notion is bolstered by a number of works related to the satisfaction of basic needs and

regime survivability. The implications of this on-going dilemma points to the notion that there will be little economic growth let alone a vibrant post-transition regime in Cuba without a secure and reliable energy infrastructure.

Given this less than sterling appraisal of Cuban energy prospects, the potential role of the United States and the international community in the energy sector could be very influential. One could surmise that the U.S. firms and government agencies will desire to play a leading role in the revitalization of the Cuban infrastructure. This is likely because of the following factors. U.S. firms such as Boise Cascade have already established certified claims against the Cuban government for its former holdings in the energy sector. They and other firms like them would in all likelihood be interest in investigating a return to Cuba to conduct business. U.S. government agencies such as the Nuclear Regulatory Commission, the Department of Energy, and USAID will play a significant role in re-establishing ties with like government agencies in Cuba to conduct technical exchanges and information sharing in areas of mutual interest. Presently, the foreign policy toward Cuba severely limits contact between government officials in virtually any setting including scientific conferences. Many of the concerns related to Cuba's exploitation of nuclear energy could be definitively addressed by an exchange of qualified technicians capable of conducting an objective review of issues presently under question. Finally, international lending agencies such as the World Bank as well as private lending institutions will supply the financing of this massive undertaking. These firms and agencies will also be attracted because of the long-term nature of the work. Until a comprehensive assessment of the energy infrastructure is undertaken we can only estimate that the length of time that it will take to accomplish these tasks will be around 20 years.

To this point there is little evidence to suggest that Cuba can successfully pursue the development of a nuclear energy capability in the post-Cold War period without outside assistance. Moreover, the post-transition period in Cuba will almost necessarily require U.S. involvement to assist Cuba in modernizing the energy infrastructure. The present U.S. policy of embargo and isolation in the area of energy development serves only to drive the eventual cost of U.S. involvement higher, both in economic and political terms. Cuba has demonstrated a willingness and commitment to pursuing a path of energy development that is consistent with wider security, economic and environmental concerns. For that reason alone it is deserving of the assistance needed to satisfy the basic needs of its population.

Table 2 – Electricity Production Growth (1985-1995)

Year	*Electricity Production (Thousand Watts per hour)*	*Growth Rate*
1985	12.20	-0.7%
1986	13.17	7.4%
1987	13.59	+3.1%
1988	14.54	+6.6+
1989	15.24	+4.6%
1990	14.68	-3.8%
1991	12.74	-15.2%
1992	11.13	-14.4%
1993	11.05	-0.7%
1994	10.98	-0.6%
1995	11.19	+1.9%

Source: OECD (1996)

Table 3 – Cuba's Sectoral Energy Consumption by Percentage (1972, 1982, and 1995 in thousands of tons of oil)

Year	*Dom. Cons.*	*Energy*	*Other Ind.*	*Residential*	*Non-spec.*
1972	4,738	578	2,106	1,112	942
	(100%)	(12.1%)	(44.4%)	(23.4%)	(19.8%)
1982	10,016	947	4,884	2,229	1,996
	(100%)	(10.4%)	(48.7%)	(22.2%)	(19.9%)
1995	9,714	722	4,683	2,510	1,799
	(100%)	(7.4%)	(48.2%)	(25.8%)	(18.5%)

Source: OECD (1996)

Table 4 – Cuba's Primary Energy, GDP and Energy Intensity Changes (% pa) 1992-1995[54]

Year	D*E*	D*GDP*	D*I*
1992	-12.9%	-11.6%	-24.5
1993	-0.7%	-14.9%	-15.6
1994	-0.6%	+0.3%	-0.9
1995	+1.9%	+1.0%	+2.9

Source: OECD; The Economist Intelligence Unit (1997).

Table 5 – Electricity Consumption by End Use[55]

Year	*Domestic Consump -tion*	*Energy Sector*	*Iron & Steel Industry*	*Other Industry*	*Resident- ial*	*Non – Specified*
1972	4738	578		2106	1112	942
1973	5133	635		2281	1166	1051
1974	5416	655		2407	1224	1130
1975	5925	758		2633	1311	1223
1976	6472	838		2876	1401	1357
1977	6935	889		3082	1581	1383
1978	7554	886		3372	1763	1533
1979	8493	1030		3788	1975	1700
1980	9130	1137		3971	2117	1905
1981	9726	1037		4669	2042	1978
1982	10016	947		4884	2229	1996
1983	10133	991	103	4760	2344	1935
1984	10794	990	114	5076	2485	2129
1985	10529	697	128	4895	2682	2127
1986	11345	759	132	5359	2899	2196
1987	11644	796	145	5534	2899	2196
1988	12436	988	147	5828	3064	2409
1989	12955	1055	143	5936	3252	2569
1990	12484	1017		5852	3097	2518
1991	10921	813		5158	2730	2220
1992	9668	716		4643	2496	1813
1993	9596	714		4625	2480	1777
1994	9534	709		4595	2464	1776
1995	9714	722		4683	2510	1799

Source: OECD

54 *Cuba, EIU Country Report, 4th Quarter 1997,* The Economist Intelligence Unit Ltd. (1997), p. 6; and *Energy Statistics and Balances of Non-OECD Countries 1994-1995* (Paris: OECD/IEA, 1997) p. 116-117.

55 *Energy Statistics and Balances of Non-OECD Countries 1994-1996* (Paris: OECD, 1997), pp. 296-297.