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The Electric Power Sector in Cuba: Ways to Increase Efficiency and Sustainability

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Since the beginning of the Cuban Revolution, the electric power sector of Cuba has been managed with little regard for financial and economic issues. This approach to the power sector has a long history in the Communist bloc, as the sector was considered to have a preeminent political dimension. Lenin famously noted in 1920, "Communism is Soviet power plus the electrification of the whole country."[1] It was not considered necessary nor even desirable for this sector to pay for itself or turn a profit.

Cuba's per capita annual power consumption is about 1,300 kilowatt-hours (kWh). Table 3-1 shows Cuba's per capita GDP and per capita electricity consumption in comparison with three other countries.[2] (This

The author would like to thank two of his colleagues at the U.S. Agency for International Development (USAID), Micah Globerson and Luis Velazquez, for their great support in the preparation of this chapter, and Silvia Alvarado, Ignacio Rodriguez, and Elizabeth P. Belt for providing comments. The author would also like to thank the International Resources Group team of Evelyn Wright, Gary Goldstein, Pat Delaquil, and Adam Chambers, who modeled the power sector of Cuba using the MARKAL/TIMES platform. Working with the IRG team was a learning experience—and a pleasure.

The opinions expressed in this paper are those of the author and do not represent the views of the U.S. government. A number of the ideas discussed in this chapter were presented at different annual meetings of the Association for the Study of the Cuban Economy. The author bears sole responsibility for any errors in this chapter.

Table 3-1. Per Capita Gross Domestic Product and Electricity Consumption—Comparison of Chile, Costa Rica, Cuba, and Dominican Republic, 2008

	Gross domestic product		Electricity consumption	
Country	PPP (U.S.$)[a]	Nominal (U.S.$)[b]	Percentage coverage	Consumption (kilowatt-hours)
Chile	14,552	10,768	99	3,421
Costa Rica	10,768	6,563	99	1,786
Cuba	9,680	4,924	95	1,214
Dominican Republic	8,222	4,619	92	1,297

Source: CIA, *The World Factbook*, 2009. There is significant controversy on Cuba's National Income Accounts and different publications show very different figures for GDP. As the CIA *Factbook* is one of the few publications with data for the four countries, these data were used to construct the table.

a. GDP at Purchasing Power Parity.

b. GDP converted to U.S. dollars using the nominal exchange rate.

chapter presents electric power data comparing Chile, Costa Rica, Cuba, and the Dominican Republic.)

The power sector in Cuba is controlled almost entirely by the state; the only private participation is in the form of independent power producer arrangements. The situation is somewhat different in the hydrocarbon sector, as there has been significant private participation in exploration and crude oil production since the 1990s. This is the result of the very attractive production-sharing agreements (PSAs) offered in Cuba. But international trade in oil and derivatives—refining, distribution, and pricing—do not seem to follow financial and economic considerations there. This lack of concern for financial and economic pressures may result from the fact that both the Soviet Union and Venezuela have provided large subsidies to Cuba by supplying oil and derivatives on concessionary terms, and Cuba's economic policymakers do not seem to take account of opportunity costs in the energy sector (see also chapter 2 of this volume).

The power and hydrocarbon sectors are inextricably linked, as Cuba produces about 85 percent of its power using liquid fuels, a very high percentage compared with other countries.[3] The total value of the energy consumed in Cuba has been estimated at 14 percent of GDP, compared with a world average of about 10 percent. In 2007, domestic production of crude oil accounted for about 40 percent of total consumption and the rest was imported from Venezuela. About 50 percent of the total supply of fuel oil is applied to power generation and 50 percent for transportation and other uses; this is consistent with the usage breakdown seen in other countries.

Table 3-2. Cuba's Liquid Fuel Supply, 2007

Liquid fuel sources	Billions of barrels/day	Percentage of total
Domestic production	68,000	40
Imports	102,000	60
Total supply	170,000	100
Liquid fuel uses		
Power generation	85,700	50
Transport	84,300	50
Total uses	170,000	100

Source: Author's compilation based on Manuel Cereijo, "Cuba's Power Sector: 1998 to 2008," paper presented at the 18th annual meetings of the Association for the Study of the Cuban Economy, Miami (August 2008), and Oficina Nacional de Estadísticas de Cuba, *Anuario Estadístico de Cuba 2008* (Havana: 2009), tables 10.1 through 10.19.

Main Trends in the Cuban Power Sector

Until 1959, Cuba had four electric utilities, all regulated by the Public Service Commission under the Ministry of Communications, with additional power supplied by the large sugar mill industry. Most of the boilers and turbine generators used to produce energy came from the United States or West Germany. After the revolution, the entire sector (generation, transmission, and distribution) was nationalized and absorbed into a state-owned utility, Unión Eléctrica, which is under the Ministry of Basic Industry (Minbas).

The development of the sector since the revolution can be divided into three distinct periods:[4]

—1959 to 1989. These three decades, beginning with Castro's takeover and ending with the fall of the Soviet Union, saw rapid growth in Cuba's energy sector, facilitated by subsidized Soviet oil imports and other forms of financial support. The period included the country's largest buildup in energy generation infrastructure and the highest rates of growth in consumption, made possible by oil and products imported from the Soviet Union at highly subsidized prices.

—1990 to 1997. This was the so-called special period (*periodo especial*), after the breakup of the Soviet Union, when the Cuban economy was subjected to extreme survival pressure with sharp declines in GDP and the introduction of some measures to promote private sector activity. Domestic oil production accelerated and Cuba began to use fuel oil in the seven large generation plants. Unfortunately, the domestic oil's high sulfur levels severely damaged the generation infrastructure. The special period came to an end

when the economy stabilized, partly as a result of massive Venezuelan financial support.

—1998 to 2010. This most recent period has been characterized by Venezuelan support, the blackouts of 2004–05 (caused by power plant breakdowns), the energy revolution (*revolución energética*) of 2005–06 (a program to reduce electricity consumption and to expand generation capacity), and the independent power production arrangement with a Canadian company, Sherritt, whereby power is being produced by combined-cycle gas turbines supplied by that company. The *revolución energética* was successful in introducing energy efficiency, but the increases in generation, with the exception of the Sherritt deal, are based on small generator sets, called gensets, that are highly inefficient. The sector is significantly more stable now than it was during the period of the blackouts. Still, the high proportion of generation from burning liquid fuels results in extremely high costs and very high carbon emissions. The financial sustainability of the sector depends almost totally on the largesse of Venezuela. If support from Venezuela were reduced or terminated, the power sector would require extremely high subsidies. The government of Cuba does not have adequate fiscal resources for this kind of subsidy, and it would be forced to embark on an economic reform effort more comprehensive than the one experienced during the *periodo especial*, following the dissolution of the Soviet Union.

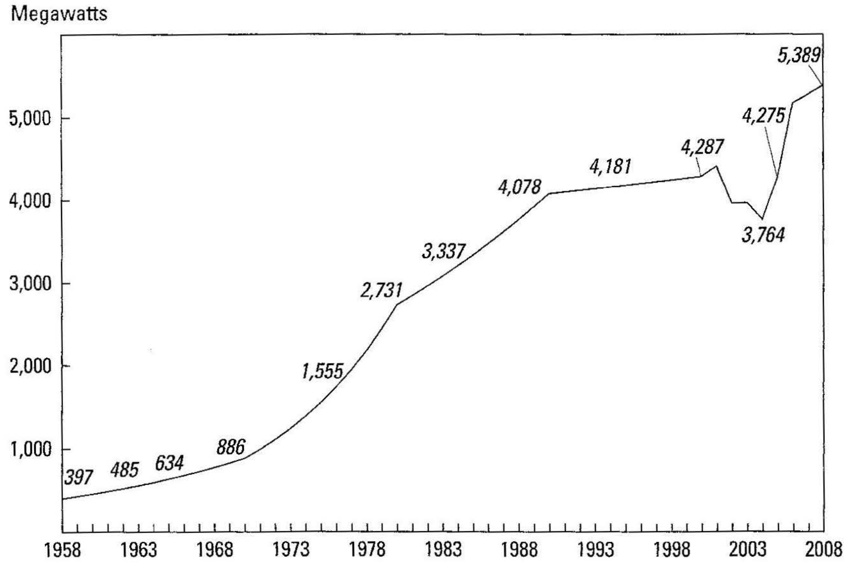
These trends will be discussed in greater detail, with particular emphasis on the most recent period.

Installed power generation capacity increased from less than 400 megawatts (MW) in 1958 to about 4,000 MW in 1990, an annual compound rate of growth of almost 12 percent. During the same period, total electricity consumption grew from about 1,500 gigawatt-hours (GWh) to about 9,700 GWh, an annual growth rate of 6 percent (see figure 3-1).

When Cuba lost Soviet assistance, which was estimated at $5 billion to $7 billion annually, it suffered a sharp decline in GDP, accompanied by a rapid decline in energy consumption per capita in the period from 1990 to 1995 (see figure 3-2). A drop in consumption by "industry and construction" accounted for most of the decline, as other types of consumers, including households, did not curtail consumption.

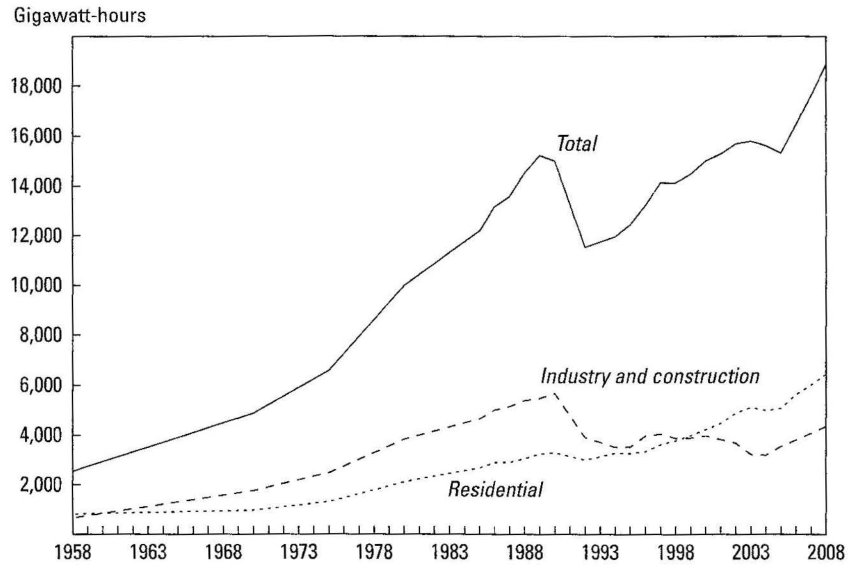
By 2005 and 2006, power plant breakdowns caused a wave of severe blackouts, sometimes lasting up to eighteen hours per day, which led to civil unrest. As a result of the blackouts the government of Cuba embarked on the *revolución energética*, to reduce electricity consumption and to expand generation capacity.

Figure 3-1. Cuba's Installed Generation Capacity



Source: Author's compilation based on data from Oficina Nacional de Estadísticas de Cuba, *Anuario Estadístico de Cuba 2006* (Havana: 2006), chapter 8, "Energía" (www.one.cu/aec_web/paginas_de_textos/c_viii.htm).

Figure 3-2. Electricity Consumption, by Key Sector, 1958–2008



Source: Author's compilation, based on data from Oficina National de Estdísticas de Cuba, *Anuario Estadístico de Cuba 2006.*

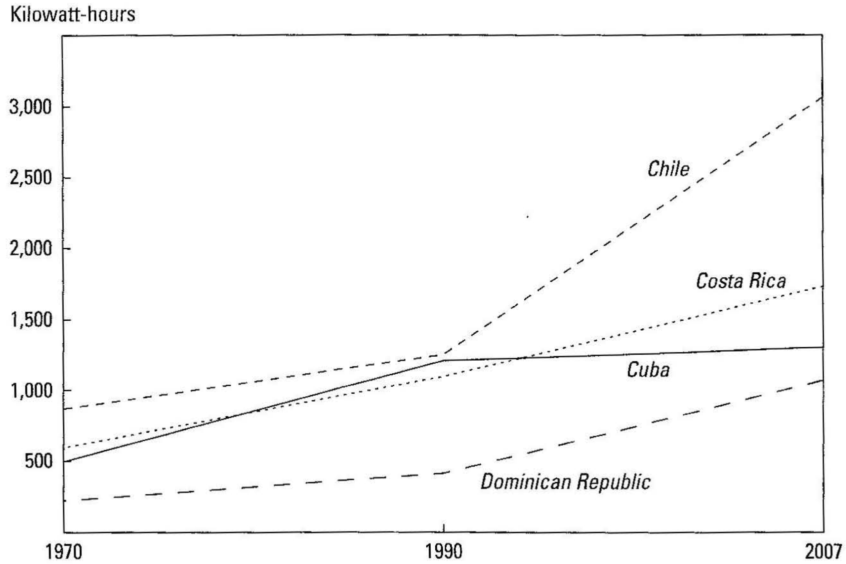
The *revolución energética,* which largely emphasized energy conservation, was reasonably successful in reducing daily peak demand. The conservation component of this program involved removing individuals' energy-inefficient refrigerators, fans, and air conditioners, and replacing them with energy-efficient appliances and light bulbs. These upgrades were somewhat compulsory, and were incentivized in various ways, including the use of payment plans of up to ten years for the purchase of improved devices, with payments discounted directly from salaries.[5]

The results of the initiatives to expand capacity, on the other hand, are mixed. The two principal elements of the production component of the energy revolution were the installation of a new distributed generation system ("distributed generation" refers to generating power close to the point of consumption) based on small gensets, called *grupos electrógenos,* that use thousands of small fuel-burning generators, and the erection of gas-fired generation plants established under a power purchase agreement (PPA) with Sherritt. The latter measure has been a highly positive development that has significantly reduced both generation costs and carbon emissions.

But the distributed generation project had distinct drawbacks. Distributed generation is an extremely costly source of power if fuel is valued at its international price. The distributed approach employed a couple thousand small gensets scattered around nearly 70 percent of the island's 169 municipalities. The mini-generators had been produced in South Korea, Germany, and Spain.[6] This investment began in 2005 and continues to provide a high-cost, low-efficiency 1.5 GW of additional energy output. Cuba also established a small wind power plant that produces about 20 megawatts; Cuba is reportedly also considering other renewable options, such as ethanol fuel from sugarcane.

The *grupos electrógenos* approach has special benefits for Cuba but also some significant costs. Distributed generation offers increased production flexibility in the face of hurricanes, which have been particularly frequent in recent years, averaging more than one per year over a fifteen-year period. Whereas the shutdown of a large generator would have an immediate impact on a delicate energy system, individual failures of smaller generators will have a more localized effect in a smaller region. Thus, the increased number of individual sources reduced overall systemic risk of a large blackout. The smaller units were also simple to install and put into service quickly, immediately ending blackouts and muting public disquiet. There are, however, distinct disadvantages to this approach: very high operating costs, at the normal international price of diesel oil and fuel to run the generators; the challenge of providing maintenance and service to thousands of generator

Figure 3-3. Per Capita Electricity Consumption—Comparing Cuba, Chile, Costa Rica, and Dominican Republic



Source: Author's compilation, based on Central Intelligence Agency, *The World Factbook* (www.cia.gov/library/publications/the-world-factbook).

units; the difficulty of efficiently dispatching numerous scattered generators (in a power system, there is always a dispatch center, which orders different generators to provide electricity to the grid); and the probability that transmission stability problems will arise.

It is interesting to compare per capita electricity consumption rates in different countries (see figure 3-3). Note that whereas Costa Rica, Chile, and Cuba had similar consumption per capita in 1990, consumption in Chile and Costa Rica today is significantly higher than in Cuba. Chile, which relies mostly on private investment in the power sector, increased generation much faster than Costa Rica, where the private sector plays only a minor role in the power sector.

Financial and Economic Aspects of Unión Eléctrica

Unión Eléctrica, the vertically integrated utility providing power to most of the country, was established in 1960. Financial data for Unión Eléctrica are not available, so the financial analysis presented in this section should be

considered approximate.[7] More research is needed to refine the numbers—an important task, given the centrality of the energy sector to the Cuban economy in general and to the fiscal accounts in particular. A further challenge in understanding Unión Eléctrica's financial profile is the dual monetary system—the use of both pesos and dollars in the Cuban economy. This imposes important conceptual difficulties, as it is very difficult to compare financial flows in U.S. dollars with financial flows in pesos. We use the official exchange rate of one Cuban peso (1 CUP) to one dollar, but we carry out sensitivity analysis to determine the effects on our conclusions of different exchange rates. Furthermore, as most workers in Cuba are employed by the state or by state-owned enterprises, the government essentially establishes wages throughout the economy, and consequently it is very difficult to speculate about the opportunity cost of labor—what the labor would have produced in its best alternative use.[8]

The following analysis, developed from multiple sources, is a rough approximation of Unión Eléctrica's actual financial situation. The main parameters and assumptions used to estimate the 2008 cash flow are the following (all dollar amounts are U.S. dollars unless otherwise indicated):

—Total value of sales: $2.8 billion.[9] Applying present rates to net sales (total sales minus losses and minus plant load) results in a figure of $2 billion. The higher figure, which came from the analysis of Manuel Cereijo, was used in this analysis; if the lower figure were used, the results would be much more negative.

—Number of workers: 33,950

—Total wage bill: CUP 266 million

—Total use of fuel for power generation: 28 million barrels

—Average cost of crude oil at international prices in 2008: $100 per barrel

—Average cost of power generation fuel at international prices in 2008: $125 per barrel

—Estimated total value of assets: $6.8 billion

—Annualized capital cost, at 10 percent interest, for twenty years: $794 million

—Operations and maintenance costs: 1.5 percent of total asset value: $101 million

In 2008, the economic profit of Unión Eléctrica was estimated to be negative, a loss of $1.9 billion, with an EBITDA (earnings before interest, taxes, depreciation, and amortization) of approximately –$1.1 billion. If the value of Venezuelan fuel is discounted by 40 percent, EBITDA becomes

Table 3-3. Oil Price Forecasts for 2009, as of January 15, 2009

Morgan Stanley	$82	CIBC World Markets	$50
Barclays Bank	$76	Goldman Sachs Group	$45
Analyst consensus (Reuters)	$58	JP Morgan Securities	$43
U.S. Dept. of Energy	$51	Purchasingdata.com	$43

Source: "Oil Price Forecasts Stay Low" (www.purchasing.com/article/CA6628617.html).

positive, around $329 million.[10] Unión Eléctrica's situation improved following the sharp decline in oil prices in late 2008. At current crude oil prices of about $70 per barrel and assuming a constant refining margin of $25 per barrel, an even exchange rate of CUP 1 = $1, and a 40 percent fuel discount, EBITDA was estimated at a positive $833 million. Many allege that Cuba pays nothing for Venezuelan oil. If that is the case, the EBITDA for Unión Eléctrica may exceed $2.4 billion, even if Cuba pays international prices for the domestic oil that it purchases through private companies participating in the production-sharing agreements.

Table 3-3 shows 2009 crude oil price forecasts from eight major institutions, ranging from $43 to $82 per barrel. If the average price of crude oil reaches $70 per barrel this year, which is roughly the average of the estimates, Unión Eléctrica faces economic losses of $1 billion (see table 3-4),

Table 3-4. Unión Eléctrica's Estimated Financial Results (Variation in Profit and EBITDA as a Function of the Price of Crude Oil), 2008[a]

	Price of crude oil per barrel ($)				
	30[b]	40[c]	60	87[d]	100[e]
Fuel price (80 percent fuel oil, 20 percent diesel) ($/barrel)	55	65	85	112	125
Economic profit ($ millions)	97	–184	–746	–1,504	–1,870
EBITDA (fuel at international price) ($ millions)	891	610	48	–710	–1,076
EBITDA (fuel discounted 40 percent) ($ millions)	1,508	1,340	1,003	548	329
EBITDA (fuel discounted 100 percent) ($ millions)	2,436	2,436	2,436	2,436	2,436

Source: Author's compilation based on Manuel Cereijo, "Cuba's Power Sector: 1998 to 2008," and Oficina Nacional de Estadísticas de Cuba, *Anuario Estadístico de Cuba 2008.*

a. This table assumes a uniform refining margin of $25 per barrel of oil in 2008.

b. Crude oil price for Unión Eléctrica's breakeven point is estimated at approximately $33.30/barrel.

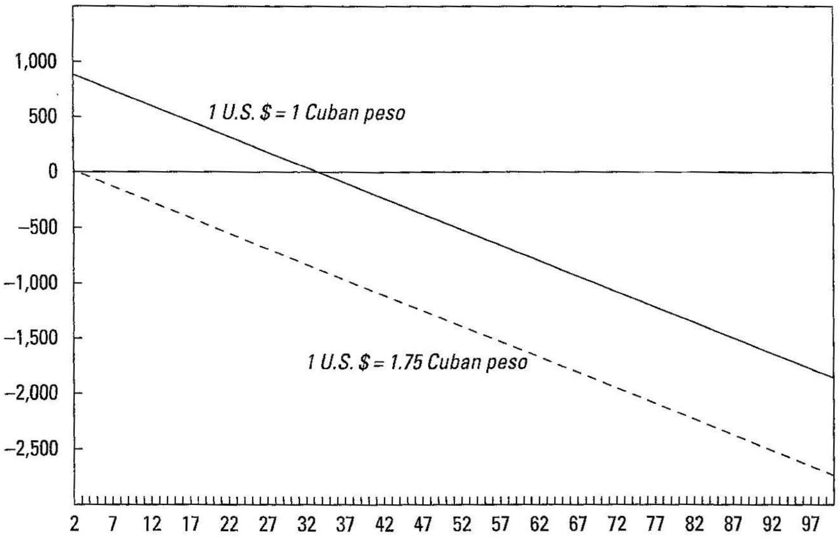
c. Average crude oil price in 2009 (two months only).

d. Average crude oil price in 2007.

e. Average crude oil price in 2008.

Figure 3-4. Economic Profit as a Function of Crude Oil Price, 2008

U.S. dollars and Cuban unconvertible pesos



Source: Author's compilation, based on data from Oficina Nacional de Estadísticas de Cuba, *Anuario Estadístico de Cuba 2006.*

and EBITDA would be a negative $233 million, if Cuba were to pay the full international price.

Unión Eléctrica's results depend critically on the market price of crude oil. For most countries that, like Cuba, base their power generation largely on liquid fuels, a reduction of the price would be good news. In the case of Cuba, however, a significantly lower price for crude oil may also lead to energy insecurity if low oil prices also result in a major reduction in Venezuelan subsidies. If the crude oil price declines, Venezuela's dire economic situation would deteriorate further, making it harder to continue to subsidize Cuba's energy needs. This highlights a critical vulnerability in the Cuban power sector: its dependence upon a stable relationship with its main foreign donor, Venezuela.

Economic profit and EBITDA were calculated over a range representing historical crude oil prices in 2007 and 2008, as well as prices in 2009 (see table 3-4). Oil price forecasts fall throughout this range, but average around $56 per barrel. Unfortunately, these calculations show Cuba as having an economic profit shortfall as long as prices exceed $33, which is an amount below the current international market price for crude. The effect of oil prices on economic profit is shown in figure 3-4, which also depicts the relationship

Table 3-5. Economic Profit as a Function of Crude Oil Prices and Exchange Rates: Sensitivity Analysis for Exchange Rates, Crude Oil, and Fuel Prices

		Exchange rates (CUP/U.S. $1)			
		1	1.5	1.75	2
Unión Eléctrica sales revenue and economic profit (million U.S.$)		2,803	2,015	1,790	1,621
Net economic profit (π) when crude oil price ($/bbl) is . . .	and fuel price, after refining (80% fuel oil, 20% diesel) ($bbl), is				
2	27	883	204	10	–136
5	30	799	120	–74	–220
10	35	658	–21	–215	–360
15	40	518	–161	–355	–501
20	45	378	–302	–496	–641
25	50	237	–442	–636	–782
30	55	97	–583	–777	–922
40	65	–184	–864	–1,058	–1,203
60	85	–746	–1,425	–1,619	–1,765
87	112	–1,504	–2,184	–2,378	–2,523
100	125	–1,870	–2,549	–2,743	–2,889

Source: Author's compilation based on Manuel Cereijo, "Cuba's Power Sector: 1998 to 2008," and Oficina Nacional de Estadísticas de Cuba, *Anuario Estadístico de Cuba 2008.*

between the economic profit and the price of crude oil under the assumption that the equilibrium exchange rate is 1.75 CUP = $1.0. At this rate of exchange, the break-even price for crude oil is slightly above $2.

The data that underlie the graph in table 3-4 are presented in table 3-5, which estimates economic profit as a function of the fuel price and of the exchange rate. If the "correct" exchange rate is 1.75 CUP = $1.0 and if the price of oil were to be US$70 per barrel (average forecast of seven institutions is presented in table 3-3), the economic losses of Unión Eléctrica would be about $1.0 billion.

Unión Eléctrica is an inefficient enterprise by international standards, with very low labor productivity, high technical losses, and an overreliance on liquid fuels. Table 3-6 summarizes key indicators for Unión Eléctrica and compares the Cuban power sector to those of Chile, Costa Rica, and the Dominican Republic. The ratio of employees to 1,000 connections at Unión Eléctrica is 9.0, compared to 5.1 in the Dominican Republic, 3.8 in Costa Rica, and 0.7 in Chile. Losses (mostly technical, as there is almost no energy theft in Cuba) are 143 percent of those in Chile and 88 percent of those

Table 3-6. Productivity and Efficiency of Power Sectors—Comparison of Chile, Costa Rica, Dominican Republic, and Cuba

Indicator	Chile	Costa Rica	Dominican Republic	Cuba
Total number of connections	4,861,913	1,236,847	914,279	3,923,650
Total number of residential connections	4,486,053	1,080,591	844,613	3,773,720
Total electricity sold per year (megawatt-hours)	29,000,000	11,800,000	3,719,640	13,892,760
Electricity sold per connection (megawatt-hours/year)	6.5	10.9	4.4	3.7
Total electricity losses (percent)	6.5	8.4	42.5	15.8
Total employees in power sector	3,136	4,155	4,317	33,949
Employees per 1,000 residential customers	0.7	3.8	5.1	9

Source: World Bank, "Benchmarking Data of the Electricity Distribution Sector in the Latin American and Caribbean Region, 1995 to 2005" (http://info.worldbank.org/etools/lacelectricity/home.htm).

in Costa Rica. Losses in the Dominican Republic, a country with massive energy theft, are much higher than in Cuba.[11] In 2003, Cuba ranked fifth in the world for percentage of total energy derived from liquid fuels. This excessive dependence results in very high unit generation costs, as fuel accounts for 70 to 80 percent of total generation costs. Table 3-7 shows unit electricity costs as a function of crude oil prices. Even if losses were eliminated, costs per kWh would be about $0.33 (with crude oil priced at $100 per barrel)—a cost level that would make just about any economic activity uncompetitive in international markets.

At present crude oil prices, fuel accounts for more than 60 percent of total Cuban electricity costs (see table 3-8). Increases in labor productivity and

Table 3-7. Unit Costs of Electricity—Sensitivity Analysis to Crude Oil Prices, 2008[a]

Crude oil price ($/bbl)	Fuel price (80/20 percent fuel oil/diesel) ($/bbl)	Cost per kilowatt-hour sold ($/kWh)	Cost per kilowatt-hour generated ($/kWh)
30	55	0.1943	0.1532
40	65	0.2145	0.1691
60	85	0.2549	0.2009
87	112	0.3093	0.2439
100	125	0.3356	0.2646

Source: Author's compilation based on Manuel Cereijo, "Cuba's Power Sector: 1998 to 2008," and Oficina Nacional de Estadísticas de Cuba, *Anuario Estadístico de Cuba 2008*.

a. This table assumes a uniform refining margin of $25 per barrel of oil in 2008.

Table 3-8. Percentage Production Costs as a Function of the Price of Crude Oil, 2008
Percent of price per barrel

	Price of crude oil per barrel ($)			
Cost	30	40	60	87
Labor	9.80	8.90	7.50	6.20
Fuel	57.10	61.10	67.30	73.00
Operations and maintenance	3.70	3.40	2.90	2.40
Annualized capital	29.30	26.60	22.40	18.40
Total costs (fuel 100%)	100.00	100.00	100.00	100.00

Source: Author's compilation based on Manuel Cereijo, "Cuba's Power Sector: 1998 to 2008," and Oficina Nacional de Estadísticas de Cuba, *Anuario Estadístico de Cuba 2008.*

reductions in losses can reduce costs per kWh, but major decreases are not possible unless fuel costs decline through greater plant efficiency and by moving to other less costly sources of power generation, including renewables. Tables 3-9 and 3-10 summarize the sensitivity analysis that shows the effect of different exchange rates on Unión Eléctrica's financial and economic results. Not surprisingly, higher exchange rates make the situation worse.

Future Development Prospects for the Cuban Power Sector

The Cuban power sector will require extensive investment, competent and professional management, and sector restructuring to reduce high operat-

Table 3-9. Economic Profit as a Function of the Exchange Rate[a]

	Sales revenue		Totals in U.S.$ under varying exchange rates (CUP/$1)			
Revenue and expenditures	Local (CUP)	Foreign (U.S.$)	1	1.5	2	3
Sales revenue	2,365	438	2,803	2,015	1,621	1,227
Expenditures						
Labor	266	0	266	177	133	89
Fuel	0	3,511	3,511	3,511	3,511	3,511
Annualized capital		794	794	794	794	794
Operations and maintenance	61	41	101	81	71	61
Total expenditures	327	4,346	4,673	4,564	4,509	4,455
Economic profit	2,038	–3,908	–1,870	–2,549	–2,889	–3,228
Cash flow			–1,076	–1,755	–2,095	–2,434

Source: Author's compilation based on Manuel Cereijo, "Cuba's Power Sector: 1998 to 2008,"and Oficina Nacional de Estadísticas de Cuba, *Anuario Estadístico de Cuba 2008.*

a. Calculated for average crude oil price of $100/barrel and a refining margin of $25/barrel.

Table 3-10. Breakeven Rates for Equilibrium as a Function of Exchange Rates[a]

	Rate of exchange (CUP/$1)			
	1	1.5	2	3
Total sales revenue (U.S.$ millions)	2,803	2,015	1,621	1,227
Net energy sold (gigawatt-hours)	13,925	13,925	13,925	13,925
Total costs (U.S.$ millions)	3,549	3,440	3,386	3,331
Unit sales revenue (U.S.$/kilowatt-hour)	0.201	0.145	0.116	0.088
Breakeven rate (U.S.$/kilowatt-hour)	0.255	0.247	0.243	0.239
Economic profit (U.S.$ millions)	0	0	0	0

Source: Author's compilation based on Manuel Cereijo, "Cuba's Power Sector: 1998 to 2008," and Oficina Nacional de Estadísticas de Cuba, *Anuario Estadístico de Cuba 2008*.

a. This table assumes a uniform refining margin of $25 per barrel of oil in 2008.

ing costs and to meet growing demand in the coming years.[12] As discussed in previous sections, power generation in Cuba relies primarily on a set of aging oil-burning plants, whose condition has been compromised by the burning of heavy, sour domestic crude oil. These plants have been supplemented recently by natural gas plants, financed through international joint ventures and by new, small gensets generating a total of more than one gigawatt (GW). Going forward, the system is subject to a large number of uncertainties, including the rate of economic growth and international fuel prices. Other uncertainties—such as the rate and nature of market liberalization, openness to and availability of foreign investment, and changes in the structure of energy demand—are particular to the Cuban situation. Decisions about investment in new generation capacity will involve weighing several interlocking factors: capital versus operating costs, future fuel cost risk, future demand growth, demand-side versus supply-side investment, availability of domestic and foreign investment capital, and environmental considerations.

Cuba also faces uncertainty with respect to the ability and willingness of Venezuela to continue to subsidize the island. If the subsidies end or are reduced, Cuba will find it difficult to generate the fiscal resources necessary to continue to operate the power system at present levels of generation and tariffs (the cost of electricity).

The MARKAL/TIMES modeling platform represents all energy-producing and -consuming sectors in an integrated and highly transparent framework at a user-specified level of end-use, technology, and pollutant detail. The MARKAL/TIMES energy systems analysis toolbox is well suited to examine interlocking uncertainties through a systematic approach, and includes

a model to analyze future capacity investment decisions designed to increase the efficiency of the power system. This modeling paradigm has been in use for more than thirty years at more than two hundred institutions worldwide. The platform has become one of the leading energy-systems modeling frameworks currently in use for several major international and global applications, and for national strategic planning in dozens of developed and developing countries.[13]

In the interest of simplicity and short model construction time, the Cuba MARKAL/TIMES model development and analysis effort focused on the supply and power sectors only, to show electricity demand growth in a simple summary fashion. This section summarizes the model's results.

The goal of the analysis was to identify cost-effective power-sector investment options under various scenarios of electricity demand growth, oil and gas production, and other key energy-system variables over the 2007–25 period. The key uncertainties were divided into two scenario sets, or "storylines." The first is a business-as-usual case that assumes continued moderate electricity load, limited foreign investment in the oil and gas sector, and hence, limited production growth. The second, high-investment case assumes rapid economic and electricity demand growth, high foreign investment, rapid increase in domestic fuel production, and transition to market pricing of electricity. Within each scenario set, sensitivity analyses were conducted on key variables, including higher gas prices, lower oil prices, restrictions on the feasible rate of investment in new power plant and liquefied natural gas (LNG) import infrastructure, and high bagasse availability owing to a revitalized sugar and ethanol industry (bagasse is the fibrous residue left after sugarcane is crushed to extract juice). The scenarios are summarized in table 3-11.

The key results were found to be robust across these multidimensional hypotheticals. Natural gas was found to be the most cost-effective fuel, even in cases where natural gas prices were increased 40 percent above AEO2009 (annual energy outlook for 2009) projected levels and oil prices were set at 40 percent below AEO2009 levels. The model found it to be most cost-effective to replace the existing heavy fuel oil power plants with new natural gas combined-cycle plants as quickly as possible, as a result of low efficiencies, low availabilities, and high maintenance costs of the existing plants. Sensitivity analysis found this conclusion to be robust even when assumed maintenance costs were reduced by half.[14]

Given these results, the key uncertainty is access to natural gas through domestic production and imported liquid natural gas. Generic assumptions

Table 3-11. Development Scenarios and Sensitivity Cases

Development scenario	Characterized by	Sensitivity cases
Business as usual	Moderate electricity demand growth in line with recent trends	Higher gas prices
	Slow growth in oil and gas production in line with recent trends	Lower oil prices Limited rate of new investment No liquid natural gas imports available Higher bagasse volume available
High-investment, high-growth	Rapid economic growth High foreign investment Accelerated oil and gas production growth	Higher gas prices Lower oil prices Limited rate of new investment
	Transition to market electricity prices	No liquid natural gas imports available Higher bagasse volume available

Source: Author's compilation based on Manuel Cereijo, "Cuba's Power Sector: 1998 to 2008," and Oficina Nacional de Estadísticas de Cuba, *Anuario Estadístico de Cuba 2008.*

from the U.S. Energy Information Administration were used to characterize LNG import costs. Under these assumptions, importing LNG was found to be cost-effective in every scenario, suggesting that further examination of site-specific LNG infrastructure costs is an important area for future study. Restricting LNG imports substantially increased system costs in every scenario. When LNG import was denied as a model option, wind and sugarcane bagasse resources were used, although they played a marginal role in the non-restricted scenarios—those in which the ability of Cuba to finance new natural gas plants and a regasification plant is not constrained.

A second key uncertainty is how rapidly existing plants can be replaced. In the high-growth, high-investment case, the unconstrained system built nearly 3 gigawatts of gas combined-cycle generation in the 2012–14 period, at a cost of $2.5 billion. This rate of construction and investment may be unrealistic because of both economic and physical construction constraints. Various restrictions on the speed of this replacement were imposed, and were found to be a primary determinant of system costs and electricity prices.

Current electricity tariffs are subsidized, at an estimated average cost of $0.13 per kWh, or somewhat over half of current costs, assuming an exchange rate of approximately 1.75 CUP = $1. A variety of scenarios endogenizing demand response were explored.[15] The effect was primarily on medium-term demand. Once the system has completed the replacement of existing plants, subsidies are no longer needed to maintain electricity prices at or below current levels until the final periods of the modeling horizon.

In the business-as-usual scenario, limited growth in domestic gas production made the system very sensitive to changes in external conditions. A 40 percent increase in gas prices increased system cost by 15 percent, and an inability to import liquid natural gas increased system cost by 50 percent. With LNG restricted, the system retained the more efficient existing heavy fuel oil plants and built a variety of new plants burning heavy fuel oil to produce steam, wind farms, and bagasse-burning plants. When, in the unconstrained scenario, the rate of new investment was held below the 2.5 gigawatts projected to be built between 2012 and 2014, existing heavy fuel oil plants continued to operate for some time in the presence of the slower turnover.

Fuel expenditures sharply increased in 2010, as Venezuelan oil subsidies were assumed to expire. Switching to natural-gas-fired plants enabled a precipitous drop in fuel costs, even in the high-gas-price case. Limiting access to imported liquid natural gas greatly increased fuel costs, as reliance on petroleum-fired generation was extended. However, a revitalized sugar-bagasse-to-energy industry mitigated this effect by eliminating the need for imported petroleum by 2020.

In the high-investment scenario, system costs were also sensitive to increases in gas prices and restrictions on the rate of investment in new power plants, but the effect was less pronounced than in the business-as-usual case. When electricity subsidies were removed, demand growth moderated, but only slightly. The effect was most pronounced when replacement of the existing plants was slowed by investment constraints. Once the transition was completed, relatively low market prices led to only minor adjustments in demand. The only factors that significantly increased prices beyond this level were restricting new investment or denying LNG imports. Unlike in the business-as-usual scenario, in the high-investment scenario, rapidly expanding domestic gas production enabled system reliance on gas even in the absence of LNG imports, with a minor role for wind and bagasse. However, higher costs led to a downward adjustment of demand in response to market prices, suggesting that end-use energy efficiency potential and cost are important variables for further analysis.

As in business-as-usual, the switch to natural gas in the high-investment scenario enabled a substantial drop in fuel costs. However, higher demand growth left the system vulnerable to increases in natural gas prices, which substantially increased generation costs. Greater domestic production of natural gas than in business-as-usual allowed the system to obtain the majority of its fuel from domestic sources, decreasing energy security concerns.

In both scenarios, replacement of the existing plants led to a sharp drop in CO_2 emissions. By 2025, however, steady growth in generation brought emissions back nearly to 2007 levels (in the business-as-usual case) or above (in the high-investment case). Only in the renewables-heavy, LNG-restricted business-as-usual scenario were CO_2 emissions flat across the time horizon. Scenarios with CO_2 emissions prices or caps were not examined in this analysis, but such an analysis could identify opportunities for emissions reductions.

The analysis suggests the following key areas for further study:

—The cost and potential for future access to natural gas through domestic production and LNG imports

—The feasible rate of power plant replacement

—The potential for price-responsive demand adjustment through end-use energy efficiency

—The feasibility of coal generation

The Potential for Renewables in Cuba

The potential for renewable energy sources is somewhat limited, and more research is needed. Some of the conclusions of the International Resources Group report on the potential for renewables are outlined.

Hydropower

The total hydropower resource in Cuba has been estimated at 650 megawatts,[16] but much of the currently unutilized potential is in protected or naturally sensitive areas that may not be candidates for development. The remaining resource appears suited for small facilities in areas that are mountainous or have seasonal characteristics. Thus, we assumed that these resources could continue to be exploited primarily for off-grid electricity supply to rural schools, medical centers, and small villages rather than for the grid-connected demand considered in this study. Therefore, new hydropower installations were not included in the set of new power plant options.

Solar Photovoltaic

Cuba obviously has excellent solar resources—the use of solar photovoltaic generation is limited by capital cost rather than resource base. We investigated concentrated solar—the use of lenses or mirrors to focus a large area of sunlight onto a small area, whence this concentrated light is directed onto

a photovoltaic surface. We did not regard concentrated solar as a realistic grid-connected option, because of limitations in radiation and atmospheric clarity: Cuba's high ambient humidity results in low efficiencies for concentrated solar energy generation. Present photovoltaic applications are largely for off-grid uses. We developed solar PV capacity factors for Cuba from the RETscreen Clean Energy Project Analysis Software, a decision support tool developed with the contribution of numerous experts from government, industry, and academia.[17]

Wind

A preliminary estimate of Cuba's wind potential is 400 megawatts.[18] Wind capacity factors and transmission costs are always highly site-dependent, so only general estimates could be made until a detailed site inventory for Cuba was undertaken. A detailed high-resolution wind energy resource map for Cuba was created at the United States Department of Energy's National Renewable Energy Laboratory as part of the Solar and Wind Energy Resource Assessment project for the United Nations Environment Program. The wind mapping—which used a combination of analytical, numerical, and empirical methods employing GIS mapping tools and data sets—covered approximately 110,000 square kilometers of land area and, when offshore areas were included, more than 150,000 square kilometers. The resulting map highlights the major wind resource areas and provides a wind resource estimate consistent with available measurement data. The report estimated the total electricity-generating wind potential for Cuba at 2,550 megawatts for class 4 and 5 wind areas.[19]

The national wind resource map indicates mostly moderate resources; the largest area with good winds is an area offshore from Guantánamo. Mountain ridges are likely to have small localized good to excellent wind resources.

Biomass

Estimates of the sugarcane bagasse resource in Cuba were derived from work by Walfrido Alonso-Pippo in which he examined the history, methods, costs, and future prospects of Cuba's attempts to develop the energy potential of sugarcane.[20] The paper shows that sugarcane production in Cuba was historically over 70 million tons per year until the early 1990s, when production dropped dramatically, to about 35 million tons per year; it has continued a slow decline since then to about 25 million tons per year in 2009.

Table 3-12. Projections of Annual Bagasse Volume under Two Assumptions of Annual Sugarcane Production

Million tons of bagasse annually[a]

Scenario	2007	2010	2013	2016	2019	2022	2025
Low bagasse volume	25	25	25	25	25	25	25
High bagasse volume	25	30.8	36.7	42.5	48.3	54.2	60

Source: Author's compilation based on Manuel Cereijo, "Cuba's Power Sector: 1998 to 2008," and Oficina Nacional de Estadísticas de Cuba, *Anuario Estadístico de Cuba 2008*.

a. The energy content of one ton of bagasse is 2.3 petajoules.

From the 1990s to the present, the Cuban sugarcane industry's average sugarcane yield has declined from 57.5 to 22.4 tons per hectare in 2005, a 39 percent decrease. At the same time, the total amount of agricultural land in Cuba used for sugarcane cultivation has declined from 21 percent to barely 5 percent. Alonso-Pippo cites many reasons for the decline of Cuba's sugarcane industry and for the failure of the industry to recover in spite of government efforts to improve it. Despite these factors there is significant room for expanding cane production if sufficient investment and improved incentives were employed. Jorge Piñón, a former oil industry executive, puts forth two scenarios for the resource potential of sugarcane yields, one based on the current sugar industry and one based on a revitalized sugar-ethanol-bagasse industry (see table 3-12).

The bagasse, the biomass that remains at the mills after the sugarcane has been ground and crushed to extract the juice, represents only about 15 percent of the weight of the dry sugarcane. The average heat content of sugarcane bagasse is approximately 16.5 gigajoules per dry ton.[21] The potential energy available from Cuba's bagasse resource is given in table 3-13 for each of the two scenarios.

Estimated electricity production from bagasse at sugar-ethanol mills was based on the operation of a 7,000-ton-per-day sugar mill producing either sugar or ethanol. The crushing season is about three thousand hours per year.

Table 3-13. Bagasse Energy Potential in Two Scenarios

Scenario	2007	2010	2013	2016	2019	2022	2025
Low bagasse	58.5	58.5	58.5	58.5	58.5	58.5	58.5
High bagasse	58.5	72.2	85.8	99.5	113.1	126.8	140.4

Source: Author's compilation.

Table 3-14. Technology Characterization for Bagasse Plant, Capital, and Operating Costs

Capital investment	U.S.$ million
Steam saving from sugar factory	3.3
Distillery	6.4
Cogeneration capacity (33 megawatts)	50.4
Total investment	60.1
Operations and management costs (U.S.$ per kilowatt-hour)	
Fixed	0.031
Variable	0.015

Sources: Based on Amy Myers Jaffe and Ronald Soligo, *The Potential for the U.S. Energy Sector in Cuba* (Rice University, 2001) (www.cubafoundation.org/CPF-EnergyStudy.htm), and J. R. Piñón Cervera, "Cuba's Energy Challenge: A Second Look," Association for the Study of the Cuban Economy, Miami, August 2–4, 2005.

The calculation of the amount of surplus electricity that can be cogenerated is premised on efficiency improvements to reduce steam use in the sugar factory, the addition of a distillery to increase revenue, and the addition of a 33 megawatt cogeneration plant that uses a condensing-extraction steam turbine. The plant generates 92 gigawatts per year of surplus power, which is about a 32 percent capacity factor—the ratio of the actual output of a power plant over a period of time and its output if it had operated at full nameplate capacity the entire time. The capital investment cost for the steam reduction, the distillery, the 33 megawatt cogeneration plant, and the operating and maintenance costs are shown in table 3-14.

Increasing the Efficiency and Sustainability Potential of the Power Sector

No major changes would be required to achieve the "business as usual" scenario. Achieving the high-growth and high-investment scenario would require implementing different policy measures, including the rationalization of the tariff regime. Equally important would be establishing a more favorable environment for foreign investment; this is a particular challenge, as the general environment for foreign direct investment is being affected negatively by the global financial crisis.

What measures should be implemented to achieve the high-investment scenario? How can the goal be met of attracting investment of $2.5 billion for generation using combined-cycle gas turbines, plus the resources necessary to expand domestic gas production or to establish a regasification plant to handle imported liquid natural gas? As it strives to implement policies necessary to achieve the high-investment scenario, Cuba could benefit from the experi-

ence of other Latin American, Asian, Eastern European, and Central Asian nations.[22] But first, some caveats:

—These recommendations are not offered prescriptively but rather to highlight some of the main issues that will have to be faced if a Cuban government makes the decision to reform the country's power sector. The verbs "should" and "would" are used merely as shorthand, to indicate that authorities in Cuba should consider adopting the proposed measures.

—Power-sector reforms can only succeed if they are coordinated with the policies guiding reforms in other sectors. That is, tariff adjustment, protection of vulnerable groups, and private participation policies must be formulated in the context of national policies on those subjects.

—An adequate power supply is a necessary condition for rapid economic growth, so decisions on reforming the power sector are extremely important. These decisions must be made autonomously by local authorities vested with such decisionmaking responsibility, but the experiences of other countries can inform the direction taken by Cuba, and international experts can provide valuable advice.

—Models from other countries should not be applied wholesale in Cuba but rather must be adapted to local conditions.

—Most important, our recommendations rest on the premise that the Cuban government has made the decision to improve the environment for foreign investment in the power sector. Support of the U.S. government, though not absolutely indispensable, could help make Cuba's transition to cleaner and cheaper energy faster and easier. In this context, the recommendations of the recently completed report by a staff member of the Senate Committee on Foreign Relations are particularly relevant. He concluded that the United States should increase energy cooperation with Cuba.

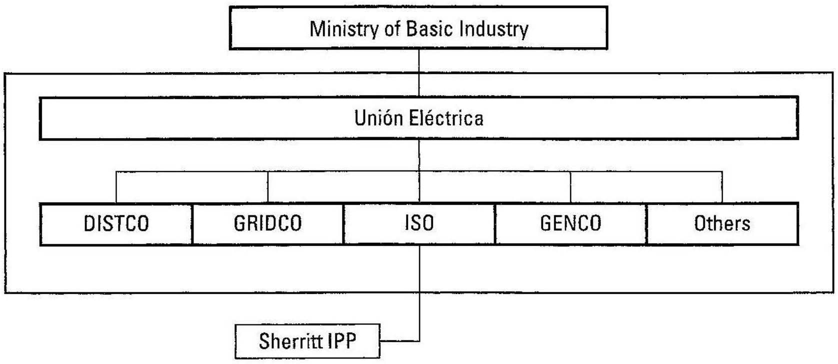
Models of Power-Sector Reform

Most of the literature on power-sector reform advocates that countries with a sufficiently large market should move to a fully competitive power system.[23] (A rule of thumb is that competition is possible in markets selling above 1,000 megawatts of installed capacity.) A way to understand the path to reform is to introduce the concept of power-sector models, which can be summarized as follows:[24]

Monopoly (Model 1)

In this model there is no competition at all levels of the supply chain (generation, transmission, distribution, and commercialization), that is, a single

Figure 3-5. Structure of Cuba's Power Sector, 2010



Source: Author's compilation.
DISTCO = distribution company.
GRIDCO = high-voltage transmission grid.
ISO = independent system operator.
GENCO = generation company.
Others = support activities (construction personnel and other assets).

company produces and delivers electricity to the final users. These monopolies can be private or state-owned. In Cuba today, Unión Eléctrica essentially dominates all aspects of the power sector. This model best represented the power sector in Cuba until the power purchase agreements with Sherritt were introduced.

Single Purchasing Agency (Model 2)

In this model a single buyer or purchasing agency buys electricity from a number of different generators, normally referred to as independent power producers (IPPs), with whom it has purchase contracts. These power purchase agreements (PPAs) are reached either through bilateral negotiations or through a competitive process. In quite a few countries, El Salvador and Guatemala, for example, the reform of the power sector began with a state-owned enterprise signing PPAs with IPPs. While these purchase agreements fulfilled the objective of supplying emergency needs, as the frequency of blackouts was reduced, some have criticized them as being costly, since many of these contracts were the result of bilateral negotiations rather than the result of competitive bidding processes. In systems that introduced competition in generation, the PPAs signed prior to the reforms represent "stranded costs" that are being paid by consumers. Cuba today follows a very limited version of model 2—it could be termed model 2 "lite" (see figure 3-5).

Wholesale Competition (Model 3)

This model represents a departure from the traditional way to manage power systems. Basically, an original monopoly is separated both horizontally and vertically. This separation, called unbundling, results in a sector structure with several generators (generating companies, or GENCOS), several distributing companies (DISTCOS), one or more transmission companies (TRANSCOS), and a dispatch center. DISTCOS purchase electricity directly from the generators they choose, transmit this electricity under open-access arrangements over the transmission system to their service area, and deliver it over their local grids to their customers. The regulator allows competition in generation but regulates the value added in distribution (VAD), that is, the markup between the wholesale cost of the electricity and the final price paid by the consumers. Regulation of the VAD is normally through a price cap.

Partial Retail Competition (Model 4)

This model is like model 3, but large customers (defined in the regulations) can negotiate prices directly with generators. This adds competition to the system, and also allows large clients with special needs, such as those with peak demand different from that of the average consumer, to negotiate terms that are favorable to them and also to the generator. This model could represent the goal of reform of Cuba's power sector three to five years after the beginning of a reform effort. I have advocated elsewhere that Cuba should eventually move to model 4, which is what predominates in Latin America; reaching that stage would I believe take three to five years after the decision to reform the sector is taken.[25]

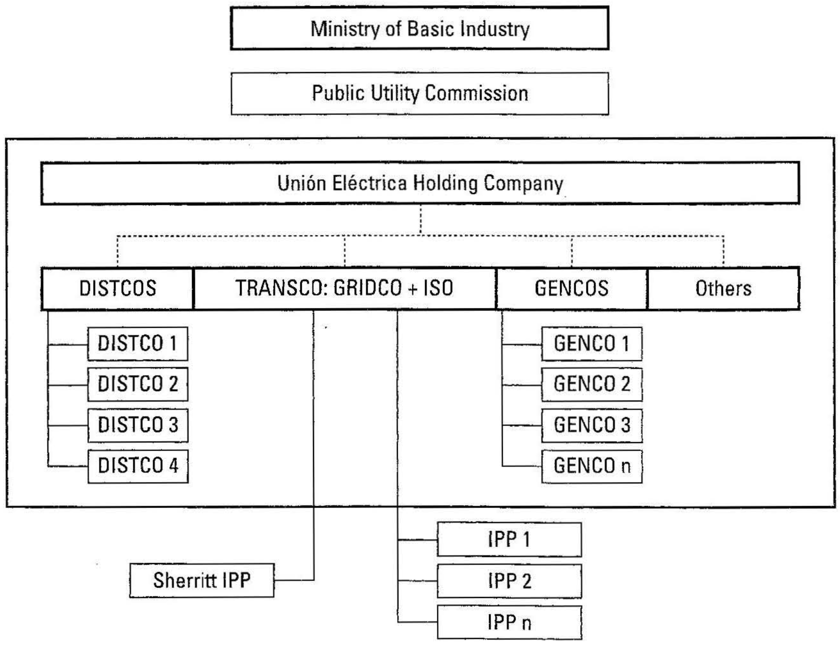
Full Retail Competition (Model 5)

Under model 5, all customers can choose their electricity supplier, under open access for suppliers to the transmission and distribution systems. This model has been implemented in California, a market design some argue was unduly influenced by ENRON.[26]

Preconditions to Modernizing the Cuban Power Sector

Here I shall identify the different measures that the government of Cuba should consider to strengthen the present power-sector model (model 2 in the literature on power-sector reform) in order to encourage foreign direct investment in generation facilities and technology. The proposed future

Figure 3-6. Structure of Cuba's Energy Sector to Achieve the High-Growth, High-Investment Scenario



Source: Author, based on proposed market reform model.
DISTCO = distribution company.
TRANSCO = transmission company.
GRIDCO = high-voltage transmission grid.
ISO = system operator.
GENCO = generation company.
Others = support activities (construction personnel and other assets).

structure necessary to achieve the high-growth and high-foreign-investment scenario is shown in figure 3-6.

Some of the steps that should be implemented to achieve the high-growth, high-investment scenario include the following:

—Pass electricity-sector legislation and establish a public utility commission

—Model the energy sector to determine optimal expansion path

—Modify tariffs so as to reach full cost recovery

—Restructure Unión Eléctrica

—Develop independent power producer arrangements

—Develop operating contracts or concessions for existing assets

Establish a Public Utility Commission

The electricity-sector law ("the law") should require the Ministry of Basic Industry (Minbas) to concentrate its efforts in the power sector on the formulation of strategy and policies, while a public utilities commission (PUC) should be established to regulate the sector. Latin American countries that have reformed their power sectors have learned the basic lesson that it is easier to develop a legal and regulatory framework than to develop adequate institutions, such as relevant ministries and regulatory commissions, whose task is policy formulation. The regulatory agencies—the public utility commission—must be independent of the former and must be accountable to a board of commissioners for its actions.

An effective autonomous regulatory public utilities commission, as set forth by Warrick Smith, has the following features:[27]

—Established by law

—Has arm's-length relationship with operators, consumers, and other private interests

—Has arm's-length relationship with political authorities

—Is financially independent (financed by a fee charged to the regulated companies) and can pay commissioners competitive salaries

—Commissioners chosen with participation of executive and legislative branches of government

—Professional criteria used for appointment of commissioner(s)

—Commissioners have fixed, staggered terms and can be removed only for well-defined cause

Independence must be balanced by accountability, which is ensured by the following:

—Strong provisions prohibiting conflicts of interest

—Established rules and procedures for appealing decisions of the regulator

—Public availability of budget and scrutiny by (usually) Parliament

—External audits

—Permitting removal of commissioner(s) for just cause

—Open hearings with participation by the regulated industries and the consumers

The staff of the public utility commission will require training on the job as well as abroad. Good possibilities for training abroad include the Public Utilities Research Center of the University of Florida, the Kennedy School of Government at Harvard (specifically, the course "Infrastructure in a Market

Economy"), and the Institute for Public-Private Partnerships, headquartered in Arlington, Virginia. Foreign consultants could provide on-the-job training and also support the PUC. Another powerful instrument for enhancing the skills of the staff of the Cuban regulatory commission would be partnerships, under the National Association of Regulatory Utility Commissions, with a U.S. state regulatory body. USAID is supporting a partnership between the regulator of Nicaragua and the regulator of Texas, and the results have been positive.[28]

Model the Energy Sector

Modeling the Cuban energy sector means assessing what would be necessary to change the power sector from model X to model Y. Ideally it would done in concert with Unión Eléctrica technicians, who would have the most accurate data and the greatest knowledge of the power system. A thorough modeling of the whole energy sector (power, transport, industry, and households) and the generation of more, and more accurate, data could help determine with greater precision the optimum path for restructuring the power system. To gain a better overview of the total energy sector, additional studies should be undertaken to provide the following:

—A more thorough analysis of the prospects for renewable energy

—The potential for and cost of future access to natural gas through domestic production and imported liquid natural gas

—Prefeasibility study for building a degasification plant and/or domestic gas transmission

—Modeling of the transmission network to determine the optimal location of power plants, including combined-cycle gas turbines

—Determination of the feasible rate of power plant replacement

—Potential for price-responsive demand adjustment through end-use energy efficiency

Modify Tariffs

A new tariff schedule should be developed that reflects new cost estimates and increases in efficiency. The preliminary analysis shows that if the sector is transformed from liquid fuels to gas and renewables, there may not be a need for major tariff increases. Any tariff changes should be established by the public utility commission and a system designed to adjust prices to reflect changes in costs be put in place.

Table 3-15. Two Scenarios for Creating Power Distribution Entities

Number of distribution areas	Province or region	Estimated number of customers (millions)	Market participation (percent)
Three distribution areas	Havana province	1.1	33.3
	Central provinces	1.2	36.4
	Eastern provinces	1.0	30.3
	Total	3.3	100
Four distribution areas	Havana province	1.1	33.3
	Central provinces, region 1	0.7	21.0
	Central provinces, region 2	0.8	22.8
	Eastern provinces	0.8	22.9
	Total	3.3	100

Source: Author's compilation based on Manuel Cereijo, "Cuba's Power Sector: 1998 to 2008," and Oficina Nacional de Estadísticas de Cuba, *Anuario Estadístico de Cuba 2008.*

Restructure Unión Eléctrica

The Cuban government should consider unbundling Unión Eléctrica by establishing separate entities according to function, under a holding company (see figure 3-6). For example, the distribution assets could be separated into three or four separate distribution companies (see table 3-15 for the possible division of those assets). Planners would need to develop a more thorough analysis of the different load centers and of the transmission network to ensure a rational, appropriate separation according to actual power markets.

Sally Hunt recommends that the system's operation and the transmission should be combined and corporatized into a combined operations and transmission company, or TRANSCO.[29] Hunt's reasoning is that combining systems operation and transmission provides a better business model and would improve coordination of power supply and demand. Transmission and system operations have been combined effectively in a number of markets, including England and Wales, Spain, and Scandinavia.[30] Some argue against this model because it concentrates too much power in one institution.

The Cuban government should consider breaking up the generation assets of Unión Eléctrica and establishing seven to eight generating companies. Additionally, a company could be established with the personnel and assets to carry out construction.

Develop Independent Power Producer Contracts

Using the results of the planning model, a transparent system should be developed for independent power producer (IPP) life-of-plant contracts

(contracts that last as long as the useful life of the asset). Some key questions need to be answered concerning the design of these contracts:

—Should the technology to be used be specified?

—Should the contracts be outside the control of the system operator?

—Should the profits be calculated as a function of the fixed assets, or the variable costs, or a combination of both?

Develop Operating Contracts and/or Concessions for Existing Assets

Cuba has demonstrated that it is ready to permit significant private participation in the provision of infrastructure services. Besides its IPP contract with Energas-Sherritt, Cuba has privatized most of the telecommunications company and developed concessions for the water utilities in Havana and Varadero, with Aguas de Barcelona and Aguas de Valencia, respectively. Cuba should also consider introducing operating contracts (incentive-based management contracts) and/or concessions for some of the state-owned generation and distribution companies.

Support by the U.S. government for the potential reforms of the power sector is severely constrained by existing Helms-Burton legislation. If legislation is modified or a waiver is granted, the American government could support technical assistance for modeling the sector to determine the potential for improving efficiency and environmental sustainability and for training government officials on economic regulation of utilities. Training possibilities include:

—Course on regulation at the Public Utilities Research Center at the University of Florida. This course takes place twice a year, in June and January.

—Course on private infrastructure at the Kennedy School of Government, Harvard University. This course is offered every summer.

—Courses on the design of IPPs and rate design at the Institute for Public Private Partnerships (IP3), which are offered several times each year.

Greater cooperation between the United States and Cuba on the energy sector, including the power sector, would present an opportunity for an enhanced dialogue that could benefit both countries.

Notes

1. Vladimir Ilyich Lenin, "Report on the Work of the Council of People's Commissars," December 22, 1920, *Collected Works*, vol. 31. Cited in the *Columbia World of Quotations* (Columbia University Press, 1996).

2. The conclusion that Cuba has a higher consumption of electricity is based on a regression of the natural logarithm of electricity consumption as a function of the natural logarithm of GDP per capita (PPP basis). Calculation by author based on data collected by the Oficina Nacional de Estadísticas de Cuba for electricity consumption and presented in *Anuario Estadístico de Cuba 2008,* Oficina Nacional de Estadísticas, 2009, table 10-13.

3. In 2003 Cuba produced 93 percent of its power using liquid fuels, the fifth-highest percentage in the world. The decline in that percentage is the result of new gas-fired facilities established under a power purchase agreement with Sherritt, a Canadian company.

4. Manuel Cereijo, "Cuba's Power Sector: 1998 to 2008," paper presented at the 18th annual meetings of the Association for the Study of the Cuban Economy, Miami (August 2008).

5. Simon Romero, "In Cuba, a Politically Incorrect Love of the Frigidaire," *New York Times,* September 2, 2007, p. A1.

6. Cereijo, "Cuba's Power Sector: 1998 to 2008," 28.

7. Financial records for Petróleos de Venezuela are also unavailable.

8. I am grateful to Jorge Sanguinetty, who raised this issue in a conversation.

9. Cereijo, "Cuba's Power Sector."

10. Officially, Cuba buys oil from Venezuela at a 40 percent discount—roughly the proportion of domestic oil that belongs to Cuba under the production-sharing agreement with foreign oil companies producing in Cuba.

11. In Cuba, energy theft is penalized with exorbitant fines and even prison. Energy theft generally is done through meter tampering or by connecting illegally to the distribution network.

12. This Section draws on Evelyn Wright and others, "A Power Sector Analysis for Cuba Using the Markal Model," *Cuba in Transition* 19: 493–96 (http://lanic.utexas.edu/project/asce/pdfs/volume19/pdfs/wrightbeltetal.pdf). This analysis was hindered by the lack of reliable data. See next note.

13. MARKAL/TIMES is an energy systems modeling platform used to construct models and analyze energy, economic, and environmental issues over several decades. This set of software tools provides a framework for exploring, evaluating, and quantifying alternative energy futures and the roles that various policy options may have on technology and resource choices. For information on MARKAL/TIMES, please see www.irgltd.com/Our_Work/Services/MARKAL_TIMES%20Demystified-v02.pdf. To understand the breadth of the MARKAL/TIMES model's applications, please see, among many other examples:

—www.sofreco.com/projets/c886/Reports.htm

—http://pesd.stanford.edu/news/chinagasreport

—www.ukerc.ac.uk/ResearchProgrammes/EnergySystemsandModelling/ESM.aspx

—http://fsi.stanford.edu/publications/20219/

—www.nrdc.org/media/2008/080513.asp.

14. Future analysis should also look more closely at the economic and financial viability of coal. The government of Cuba recently announced a plan to establish a gas regasification facility in the port of Cienfuegos. If this facility were built, gas would become the most viable source of power.

15. Endogenizing demand means allowing demand to decline in response to price increases.

16. International Solar Energy Society, Sustainable Energy Policy Concepts (SEPCO) website, Country Case Study Cuba, "Development of Cuba's Energy Supply in the Last Decade," 2005 (www.ises.org/sepconew/Pages/CountryCaseStudyCu/2.html); D. Perez, I. Lopez, and I. Berdellans, "Evaluation of Energy Policy in Cuba Using the Indicators for Sustainable Energy Development (ISED)," *Natural Resources Forum* 29 (2005): 298–307. Since 1999 the International Atomic Energy Agency (IAEA) has been leading a multinational, multi-agency effort to develop a set of energy indicators useful for measuring progress on sustainable development at the national level. This effort has included the identification of major relevant energy indicators and the development of a framework for implementation and the testing of the applicability of this tool in a number of countries. To achieve these goals, the IAEA has worked closely with other international organizations that are leaders in energy and environmental statistics and analysis, including the United Nations Department of Economic and Social Affairs, the International Energy Agency, Eurostat, and the European Environment Agency. Also, the IAEA completed a three-year coordinated research project for the implementation and testing of the original set of indicators in seven countries: Brazil, Cuba, Lithuania, Mexico, the Russian Federation, the Slovak Republic, and Thailand.

17. RETScreen Clean Energy Project Analysis Software (www.retscreen.net/ang/home.php) provided by Natural Resources Canada.

18. Perez, Lopez, and Berdellans, "Evaluation of Energy Policy in Cuba Using ISED."

19. United Nations Environmental Program, Solar and Wind Energy Resource Assessment, "Cuba Wind Energy Resource Mapping Activity," technical report, August, 21, 2006, p. 9 (www.fishermensenergy.com/dms/showfile.php?id=206).

20. Walfrido Alonso-Pippo and others, "Sugarcane Energy Use: The Cuban Case," *Energy Policy* 36 (2008): 2163–81.

21. Environmental Protection Agency, "Bagasse Combustion in Sugar Mills," background document no. AP-42, section 1.8 (www.epa.gov/ttn/chief/ap42/ch01/final/c01s08.pdf).

22. See Juan A. B. Belt, "Telecom and Power Sector Reforms in Latin America—Lessons Learned," *Cuba in Transition* 10 (2000): 374–81; Juan A. B. Belt, "Power Sector Reforms in Market and Transition Economies—Lessons for Cuba," *Cuba in Transition* 16 (2006): 75–88; Juan A. B. Belt and Luis Velasquez, "Cuba: Reforming the Power, Telecommunications and Water Sectors during a Transition," *Cuba in Transition* 17 (2007): 59–75.

23. Robert Bacon, "Appropriate Restructuring Strategies for the Power Generation Sector: The Case of Small Systems" (Washington: World Bank, 1995).

24. This typology is a simplification, and all models have nuances and "submodels." For example, in some countries, state-owned enterprises have been corporatized and subjected to additional discipline, including hard budget constraints.

25. Belt, "Power Sector Reforms in Market and Transition Economies—Lessons for Cuba," 75–84.

26. Sally Hunt, *Making Electricity Work in Competition* (New York: John Wiley, 2002).

27. Warrick Smith, "Utility Regulators: The Independence Debate," *Public Policy for the Private Sector,* note 127 (Washington: World Bank Group, 1997), 1–4.

28. Personal communication with Ing. José David Castillo Sánchez, head of the regulatory agency of Nicaragua, Erin Skootsky of National Association of Regulatory Utility Commissioners (NARUC), and Timothy O'Hare of the USAID mission in Nicaragua.

29. Hunt, *Making Electricity Work in Competition,* 302–03.

30. Ibid., 212.