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Energy Balances and the Potential for Biofuels in Cuba

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In 2002 we published a paper on Cuban energy that began with the observation "Cuba is considered a promising growth energy market in the Americas."[1] Eight years later Cuba shows even greater promise in the energy sector, but progress in realizing energy opportunities has been slow. Gaining a better understanding of Cuba's energy potential is important for policymakers in the United States, Cuba, and the Caribbean region. From the American point of view, the possibility of having an additional supplier of energy to the U.S. market located just a few miles offshore could contribute significantly to the United States' energy security. The magnitude of Cuba's energy resources is uncertain, but one estimate, by the U.S. Geological Survey, is that Cuba has mean "undiscovered" reserves of 4.6 billion barrels of conventional oil and 9.8 trillion cubic feet of natural gas in the North Cuba Basin.[2] In addition, Cuba has large land areas that once produced sugar but now lie idle. These could be revived to provide a basis for a world-class ethanol industry. We estimate that if Cuba achieves the yield levels attained in Nicaragua and Brazil and the area planted with sugarcane approaches levels seen in the 1970s and 1980s, Cuba could produce up to 2 billion gallons of sugar-based ethanol per year.

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Despite this potential, Cuba remains dependent on energy imports on a concessional basis. The collapse of its economy when assistance from the Soviet Union was terminated by that country's breakup demonstrated in a dramatic way the benefits that could accrue if Cuba became energy self-sufficient.

Cuba has been thwarted by U.S. economic sanctions and other internal domestic barriers in aggressively pursuing its own energy independence. For the time being, Havana has adopted a policy of replacing former Soviet energy assistance with current Venezuelan aid. This is a risky strategy, since Venezuelan beneficence is dependent on Caracas's own economic health, which is currently shaky.[3]

In this chapter we argue that given its rich potential in both conventional energy and biofuels, Cuba can be both energy-independent and an energy exporter.

State of the Cuban Economy

The Cuban economy suffered a major economic decline after the 1991 collapse of the Soviet Union, with GDP falling 35 percent between 1990 and 1993.[4] The economy began a slow recovery in the mid-1990s, but the extent of the recovery is disputed. International Energy Agency data show that per capita income in purchasing power parity dollars grew on average about 2 percent per annum between 1994 and 2005. CIA data show an increased growth rate for the period 2005 to 2008 ranging between 4.3 percent and 8 percent.[5] Most recently, in 2009 Cuban growth fell to 1.4 percent.[6]

The higher growth rates of Cuban GDP during the period from 2005 to 2008 reflect the increase in Venezuelan aid as well as Cuba's participation in the worldwide commodity boom and some increase in foreign investment.

The extent of Venezuelan aid is not fully transparent. Cuba is importing around 92,000 barrels a day (b/d) from Venezuela under favorable terms. Some of the oil is financed by loans, part is a barter trade involving some 20,000 Cuban medical professionals who work in Venezuela, and some oil is provided as an outright grant. Venezuela has also financed the completion of the Cienfuegos refinery, which was opened at the end of December 2007, with plans to increase the plant's capacity from around 65,000 b/d to 150,000 b/d.[7] Venezuela has also provided $122 million to finance the acquisition of tankers to carry Venezuela crude and products to Cuba.

The commodity boom has also helped the Cuban economy. Cuba is among the top six or seven largest producers of nickel in the world. Production and

export of nickel rose from 26.9 million metric tons (mmt) in 1993 to roughly 76 mmt in 2004. Output has subsequently stagnated, but new investment and capacity expansion are on the way. Nickel prices rose from $15,000/ton in 2004–05 to over $50,000/ton in early 2007. According to United Nations data, exports of nickel oxide in 2005 and 2006 each contributed over a billion dollars to Cuba's export earnings.[8] Earnings soared in 2007, with the run-up in nickel prices making nickel a close contender with tourism as Cuba's top export earner. With the onset of the worldwide recession, prices fell and fluctuated between $25,000 and $35,000/ton before plunging below $10,000 in early 2009. The collapse of nickel prices has seriously affected Cuban capacity to import and sustain per capita GDP.

Large foreign investments, in both the energy and non-energy sectors, have been announced in recent years, but it is difficult to estimate actual foreign investment, since there is always a discrepancy between announcements of investment plans and their actual completion. Cuba has not published data on foreign direct investment since 2001.[9]

In addition to Venezuela's investments, some significant projects include a Brazilian loan of up to $450 million to rebuild the port at Mariel to handle larger ships—possibly in anticipation of the end of the U.S. embargo.[10] An end to U.S. economic sanctions would allow Cuba to become an important trans-shipping hub serving overcrowded U.S. ports, possibly sidestepping U.S. environmental restrictions. (The end of U.S. economic sanctions would also open the possibility that Cuba's petroleum-refining industry could export surplus refined products to the U.S. market.) China has announced plans to invest $500 million in Cuba's nickel mining industry.[11] And Russia's Inter RAO UES, an energy company, has recently agreed to form a partnership with Cuba's Unión Eléctrica to upgrade some electricity-generating plants.[12]

Cuban growth has stagnated since 2009 for a number of reasons, most of them related to the worldwide economic recession. The collapse of nickel prices along with a drop in spending by tourists has severely reduced foreign exchange earnings. Foreign investments have been postponed, including those in the energy sector. In addition, several major hurricanes in 2008 diverted resources away from development to relief efforts and reconstruction.

The Energy Sector and Foreign Investment

In the energy area, some limited progress has been made in developing Cuba's offshore oil and gas deposits. Cuba produced about 52,000 barrels per day of oil in 2008, of which Sherritt International, a Canadian company, had an

average working interest of around 31,200 b/d.[13] Another Canadian company, Pebercan, was also active in Cuba, producing 19,000 b/d in 2008, but its production-sharing agreement with Cupet, the state-owned Cuban oil company, was terminated in early 2009. Although most of Cuba's oil potential lies farther offshore, current production comes from shallow water just off Cuba's coast, in some cases using slant drilling technology to reach deposits that lie farther off the coast. For example, the 2004 discovery at Santa Cruz has a well bore four kilometers long that extends three kilometers into the Bay of Cardenas.

Cuba also produces 3.45 million cubic meters of associated gas per day. Traditionally the gas has been piped to Havana for commercial and residential use, but with increased production, gas is now also used to produce electricity by Energas, a joint venture consisting of Sherritt, Cupet, and Unión Eléctrica, the state-owned electricity company. Energas has 376 megawatts of capacity, which is 12 percent of Cuban electricity consumption. An expansion of an additional 150 megawatts had been scheduled to begin in 2008, but has been suspended while the work schedule is being reviewed.[14]

In July 2004 Spain's Repsol-YPF identified five "high-quality" fields in the deep water of the Florida Strait, twenty miles northeast of Havana. Cuba has offered fifty-nine new exploration blocks in the area for foreign participation. Several foreign companies, including Venezuela's PDVSA (Petróleos de Venezuela S.A.), have expressed interest in joining exploration efforts in Cuba. A consortium of Repsol-YPF, Norway's Statoil–Norsk Hydro, and India's ONGC Videsh has announced plans to commence drilling a number of times. The latest projection is that drilling will begin in 2011.[15] PetroVietnam and Sinopec (China Petroleum and Chemical Corporation), the Chinese state-owned oil company, have also signed cooperation agreements with Cupet. Brazil's Petrobras, too, has indicated that it will undertake exploration in deepwater areas.[16]

The pursuit of deepwater offshore deposits may not unfold as rapidly as the news releases suggest. Exploration in these areas has been limited in the past because the technology needed to explore and develop deepwater deposits was owned by international oil companies that were severely constrained by U.S. sanctions. Today, other companies, such as Petrobras and Norsk Hydro, have the technology, but they are still reluctant to challenge U.S. sanctions. In addition, under U.S. law, ships that visit Cuban ports are barred from U.S. ports for a period of six months. If this policy is applied to drill ships, as is most likely, it will impose higher costs on oil companies. Drill ships can earn several hundred thousand dollars a day, so each day used to move them from one location to another is costly. By denying

immediate access to the U.S. Gulf, the policy forces companies to move their drilling vessels to more distant locations driving up the cost of using them in Cuba. The absence of markets for services, equipment, and supplies in Cuba itself adds to the difficulty and cost of mounting a serious exploration and production effort, because oil firms must plan and bring all equipment and other necessary materials to Cuba rather than rely on local suppliers. Jonathan Benjamin-Alvarado estimates that the absence of these suppliers adds up to 30 percent to a project's cost.[17]

Energy Balances

Cuba's energy profile has changed sharply over the years, reflecting the various periods in its economic history (see table 4-1).[18] Oil remains at the heart of energy supply, accounting for 80 percent of total primary energy supply (TPES) in 2006. Biomass, primarily from sugarcane, has also been important, but its share in TPES has decreased over time with the decline in the sugar industry. Energy supply was higher prior to 1991, because of the generous supplies from the USSR on concessional terms. After the collapse of the Soviet Union, Cuba was forced to buy its supplies in the international market, and TPES, which had fluctuated between 15,000 and 16,800 kilotons of oil equivalent (ktoe) in the preceding decade, dropped to 10,437 ktoe in 1995. Crude supply, which had been fairly consistent at around 6,800 ktoe until 1990, fell dramatically to 2,625 ktoe in 1995. The share of oil in total energy supply, which had fluctuated between 45 percent and 50 percent prior to 1990, also fell to a low of 19 percent in 1992 as Cuba shifted toward importing relatively more refined petroleum products and less crude.

The shift from importing crude to importing refined products reflected the decline in Cuba's refining capacity, the result of poor maintenance exacerbated by the loss of Soviet aid, which reduced Cuba's capacity to finance imports of parts and equipment. Another possible factor was that since Cuba no longer had access to USSR crude oil on a preferential basis, it was forced to buy at market prices. Importing refined oil products may have represented a better value than importing crude and refining it at high domestic cost.

As an aside, it is important to note that TPES measures only the energy consumed in Cuba. In fact, Cuba received much more oil from the USSR than it consumed, re-exporting a significant amount to finance imports of other goods and services. In 1985 these exports amounted to 3,500 ktoe.

The end of Soviet involvement in Cuba also brought sectoral changes in the use of energy. Although all economic sectors were affected, the residen-

Table 4-1. Cuba's Energy Profile

Kilotons of oil equivalent (ktoe)[a]

Sector and source	1975	1985	1990	1995	2000	2006
End sector						
Residential/commercial	880.3	1403.3	1470.7	986.7	1181.1	1244.6
Transportation	2,263.6	2,997.7	1,980.1	865.9	946.5	956.0
Industrial/agricultural/other	6,678.9	6,888.7	8,629.2	4,564.1	5,226.3	3,711.0
Total final consumption (TFC)	9,822.7	11,289.7	12,079.9	6,416.6	7,353.9	5,911.6
Total primary energy supply (TPES)[b]	13,184.3	14,601.7	16,834.7	10,436.8	11,500.8	10,639.0
TFC/TPES	0.745	0.773	0.718	0.615	0.639	0.556
Primary energy source						
Coal	63.4	120.8	137.4	53.0	22.0	23.0
Crude, natural gas liquids, and feedstocks	6,746.3	6,856.4	6,860.3	2,624.6	4,269.1	5,593.2
Petroleum products	2,764.4	3,508.2	3,929.5	4,734.9	3,634.9	2,860.7
Natural gas	14.2	5.7	27.5	14.1	468.8	886.1
Hydro	5.3	4.6	7.8	6.4	7.7	8.1
Combustible renewables and waste	3,590.6	4,106.0	5,872.1	3,003.8	3,098.2	1,267.9
TPES	13,184.3	14,601.7	16,834.7	10,436.8	11,500.8	10,639.0
Domestic oil production	254.6	861.1	659.6	1,446.0	2,649.2	2,850.7
Imports of crude	6,514.3	7,988.8	6,200.7	1,178.6	1,620.0	2,742.6
Energy source as share of total						
Coal	0.5	0.8	0.8	0.5	0.2	0.2
Crude, natural gas liquids, and feedstocks	51.2	47	40.8	25.1	37.1	52.6
Petroleum products	21	24	23.3	45.4	31.6	26.9
Natural gas	0.1	0	0.2	0.1	4.1	8.3
Hydro	0	0	0	0.1	0.1	0.1
Combustible renewables and waste	27.2	28.1	34.9	28.8	26.9	11.9

Source: International Energy Association, IEA Energy Balances, online subscription database (www.iea.org/stats/index.asp).

a. 1 toe (ton of oil equivalent) = 6.449 barrels for Cuba (per IEA).

b. Total primary energy supply is equal to domestic production plus net imports.

tial and commercial sectors were affected proportionately less than industry and agriculture, because the government gave priority to maintaining electrical services to households and commercial establishments. The Cuban government also undertook policies to produce a dramatic reduction in energy use in the transportation sector. Public transport was severely reduced. The number of buses operating in Havana dropped from 2,200 before the crisis to only 500 by 1993. Bus routes outside Havana were cut by two-thirds, and bicycles were imported from China as a substitute mode of transportation.[19] Energy consumption in the transport sector has never recovered from these severe cuts. Total final demand in the transportation

sector in 2005 was less than a third of its 1988 level. Similar drastic cuts were undertaken in the industrial-agricultural sector; the collapse of the sugar industry was one source of cuts as energy requirements for growing and processing sugarcane declined sharply. Total primary energy supply fell from 8,629 ktoe in 1990 to only 3,711 in 2006. Although the Cuban economy had begun to recover by the second half of the 1990s, TPES, which had fallen to a low of 10,210 ktoe in 1993, did not significantly increase, averaging only 10,822 ktoe during the period from 1995 to 2006. Crude oil supplies increased from a low of 2,254 ktoe in 1992 to 5,593 ktoe in 2006 as domestic production more than doubled and imports rose. However, this increase in crude supplies was offset by a fall in imports of petroleum products. The balance between the supply of crude and petroleum products shifted back toward its historical ratio, where crude accounted for roughly half of TPES.

In recent years the supply of natural gas, all of which is produced domestically in association with crude oil output, has increased significantly, along with the increased production of oil. Total annual supply of gas averaged 19.1 ktoe between 1990 and 1996 but rose rapidly to 896.1 ktoe in 2006.

A troubling aspect of the Cuban energy profile is the ratio of total final consumption, or TFC, to total primary energy supply, or TPES, which has shown a steady decline since 1990. This ratio is a measure of the energy lost during conversion from primary sources of energy such as coal, oil, and natural gas to secondary sources such as fuel oil, gasoline, and electricity and includes losses incurred in the transmission of electricity from the power plant to its final destination. The magnitude of these losses is affected by the sophistication of technology used in the conversion processes as well as by how well plant and equipment are maintained. The significant drop in this ratio suggests that there has been a serious decline in energy efficiency, reflecting the deteriorating infrastructure in both the electricity and refining industries. According to Mesa-Lago, the national electricity system in June 2005 functioned at only 50 percent of capacity, with blackouts lasting seven to twelve hours on a daily basis.[20] These blackouts led the government to purchase diesel generators to supplement faltering power plants, but such generators are significantly less efficient than a properly functioning central generating plant.

Forecasting Future Energy Balance: Future Energy Demand

Energy forecasting is difficult in the best of cases. For Cuba, it is even more challenging, since future energy demand will be affected by policy changes that will emerge in the coming decades. It is hard to predict when a major

change will occur and how it will play out inside Cuba. The only certainty is that the current economic development model has not been successful and will be modified or swept aside at some point. The experience of other countries that have shifted from a highly centralized command economy to one that is more decentralized and market oriented is marked by extremes. Countries in the former Soviet Union and eastern Europe suffered through a decade of economic turmoil during their transition to a market-based economy. On the other hand, China and Vietnam have experienced remarkably high rates of growth during their transitions. Cuba will be a special case and will not necessarily follow either of these patterns. Its proximity to the United States, the presence of a large expatriate Cuban community in which many members have close relatives in Cuba, and its unique history and culture will all play a role in its future direction.

In the absence of knowing how and when a transition will occur, our estimates of future Cuban energy demand are based on assumptions of various per capita income growth rates: 2 percent, 3 percent, and 5 percent per annum. These scenarios sidestep the issue of what Cuba's economic and political system will be in the future, especially during any "transition" phase. Clearly, if the experience of the former USSR is in store for Cuba, the rate of growth will be negative for a period of time and it could be a decade before there is modest growth. If China is the relevant model, then even our most optimistic scenario of 5 percent growth is conservative.

We derive future Cuban energy demand using two different exercises. First, we compare Cuba's energy use to that of countries that share some attributes with Cuba and ask what Cuba's demand would be if it had the same per capita energy use as those countries at a comparable level of per capita income. Second, we use an econometric model developed by Kenneth Medlock and Ronald Soligo that forecasts end-use-sector energy demand as a function of per capita income.[21]

Table 4-2 compares the structure and level of energy use of Cuba with that of several other Caribbean and Central American nations that share similar characteristics. For illustrative purposes, the authors have chosen the Dominican Republic, Costa Rica, and Jamaica—three countries that, like Cuba, have important tourist industries—and Guatemala, which is closer to Cuba in both population and per capita income.[22] Per capita GDP is presented in 2000 purchasing power parity dollars.[23]

Per capita total final consumption (TFC) of energy generally varies with per capita income. For Cuba and Guatemala, two countries with similar per capita income, TFC is approximately the same. For the richer countries, Costa Rica and Dominican Republic, TFC is higher. (Jamaica is an exception to this.)

Table 4-2. Breakdown of Energy Use, 2006[a]

	Cuba	Costa Rica	Dominican Republic	Jamaica	Guatemala
Population (millions)	11.3	4.4	9.6	2.7	13.0
Per capita income[b]	4,301	9,622	7,617	3,903	4,110
Per capita energy use (ktoe)					
Residential/commercial	110.5	203.5	239.9	177.9	315.6
Transportation	84.8	349.2	215.1	443.2	131.8
Industrial/agricultural/other	329.4	215.9	134.8	414.7	103.8
Total final consumption (TFC)	524.7	768.6	589.7	1,035.8	551.2
Total primary energy supply (TPES)	944.3	1,039.7	815.8	1,721.2	629.4
TFC/TPES	0.56	0.74	0.72	0.60	0.88
Energy source as percentage of total					
Coal and coal products	0.2	0.9	6.4	0.5	4.8
Crude oil, natural gas liquids, and feedstocks	52.6	15.0	26.0	22.3	1.7
Petroleum products	26.9	32.7	44.5	66.4	38.0
Natural gas	8.3	0.0	3.5	0.0	0.0
Hydro	0.1	12.4	1.5	0.3	4.0
Geothermal and solar	0.0	23.4	0.0	0.0	0.0
Combustible renewables and waste	11.9	15.5	18.0	10.5	51.5

Source: International Energy Agency, Energy Balances for Non-OECD Countries (www.iea.org), online subscription database.

a. The 2006 data are the latest available in the International Energy Agency database.

b. In 2000 PPP (purchasing power parity) dollars. This figure has recently been revised downward, to $3,500. See *CIA Factbook* (www.umsl.edu/services/govdocs/wofact2006/geos/cu.html#Econ).

The pattern of energy use, however, is very different among these countries. In Cuba, the extremely low energy use in the transportation sector is a consequence of severe restrictions imposed on the transportation sector in the wake of the cutoff of Soviet aid, as discussed earlier. Per capita energy consumption in the residential and commercial sectors is also low compared with other similar countries, a possible consequence of an underdeveloped commercial sector as well as a limited number of electrical appliances per capita. Frequent blackouts are another factor keeping consumption low.

Table 4-3 shows what the total primary energy supply would be in Cuba if its per capita level of final consumption were the same as that in the Dominican Republic and Costa Rica and at similar per capita income levels. Because of the large discrepancies in the transformation losses between Cuba and other countries and because it is unrealistic to think that Cuba can restore its energy infrastructure quickly, we assume that transformation losses as

Table 4-3. Three Energy-Use Forecasts for Cuba under Three Growth Rates—Comparison with Dominican Republic and Costa Rica

	2015			2020			2025		
Per capita growth rate	2%	3%	5%	2%	3%	5%	2%	3%	5%
Cuba's projected real GDP per capita[a]	\$5,140	\$5,612	\$6,672	\$5,675	\$6,505	\$8,515	\$6,265	\$7,542	\$10,868
Energy-use comparison (ktoe)									
If like Dominican Republic[b]	9,950	11,312	12,142	10,708	11,702	NA[c]	11,127	10,439	NA
If like Costa Rica[b]	10,938	11,285	13,037	10,682	12,340	11,844	11,753	9,969	NA
Average	10,444	11,298	12,589	10,695	12,021	11,844	11,440	10,204	NA

Source: International Energy Agency, Energy Balances for Non-OECD Countries (www.iea.org), online subscription database.

a. Income in 2000 PPP (purchasing power parity) dollars.

b. Assuming transformation losses of 40 percent in 2015, 35 percent in 2020, and 30 percent in 2025.

c. NA means that per capita income has not yet reached those levels in Dominican Republic and Costa Rica.

measured by the ratio of TFC to TPES will improve from a recent five-year average of 42 percent to 40 percent in 2015, 35 percent in 2020, and 30 percent in 2025. That would roughly place Cuba in a position in 2025 where Costa Rica, the Dominican Republic, and Guatemala were in 2006. Clearly, if Cuba can move more quickly to modernize its electrical generating and distribution facilities, demand will be lower than our projections.

If Cuban per capita income grows at 5 percent per annum, its level in 2020 will be $8,515, roughly equal to the $8,506 per capita income of Costa Rica in 2003. If total per capita sectoral end-use of energy in Cuba in 2020 were to be the same as Costa Rica in 2003, total primary energy consumption in Cuba would rise from 10,639 ktoe in 2006 to 11,844 ktoe in 2020.

Alternatively, if Cuban per capita income grows at 3 percent per annum, it will reach $7,542 in 2025, comparable to the Dominican Republic in 2006, with per capita income at $7,617. Cuba's energy consumption in 2025, using the same per capita sectoral end-use as the Dominican Republic in 2006, would be 10,439 ktoe.

Our alternative approach to estimating energy demand is to use a model developed by Medlock and Soligo that projects total final consumption in each of the end-use sectors. The model assumes that the income and price elasticities of demand for each sector are the same for all countries, and we assume that those elasticities will also apply to Cuba. In that sense, we assume that Cuba will evolve into a country that looks recognizably like others in terms of the relationship between energy use and income.

Energy demand will grow much more slowly than the model predicts if Cuba continues to discourage private ownership of automobiles and energy use in households remains low, because of either housing shortages or the cost of acquiring energy-consuming durables such as air conditioning. On the other hand, if restrictions against private automobile ownership are lifted, we might find that demand for energy in the transport sector is underpredicted as Cubans rapidly acquire automobiles to satisfy pent-up demand. Similarly caveats apply to the tourist industry, which is energy-intensive, but has not grown very much in the last few years. Future growth will be affected significantly if, for example, the United States relaxes restrictions on travel.

Our estimates, shown in table 4-4, assume that energy prices will average $55 a barrel in 2010 and remain constant in real terms thereafter. Given recent volatility in prices and the levels prevailing as of spring 2010, this may be an optimistic scenario. Clearly energy demand will be less if prices rise.[24]

Table 4-4. Energy Demand Forecasts for Cuba under Three Growth Rates, by Sector

	2015			2020			2025		
Projected per capita growth rates (%)	2	3	5	2	3	5	2	3	5
Real GDP per capita (US$)	5,140	5,612	6,672	5,675	6,505	8,515	6,265	7,542	10,868
Sector (demand in kilotons of oil equivalent)									
Residential and commercial	1,126	1,161	1,230	1,157	1,231	1,376	1,230	1,353	1,597
Transportation	1,005	1,056	1,161	1,111	1,216	1,442	1,243	1,417	1,809
Industrial and other	4,236	4,351	4,565	4,543	4,744	5,090	4,853	5,130	5,554
Total final consumption	6,366	6,568	6,956	6,812	7,190	7,907	7,326	7,899	8,959
Total primary consumption[a]	10,610	10,480	11,593	10,947	11,062	12,165	10,465	11,285	12,799
TPEC in barrels per day[b]	183	181	200	189	191	210	181	195	221
TPEC per capita[a]	900	889	984	906	916	1,007	845	911	1,033
Total primary consumption[c]	10,976	11,744	12,631	11,324	12,397	13,620	11,993	13,633	15,447
TPEC per capita[c]	931	997	1,072	937	1,026	1,127	968	1,101	1,247

Source: Authors' compilation.

a. Transformation losses are assumed to be 40 percent in 2015, 35 percent in 2020, and 30 percent in 2025.

b. Assuming 6.3 barrels = 1 ton.

c. Assuming transformation losses remain at 2006 levels of 42 percent.

We also assume that population will grow at 0.5 percent per annum, a number that is very low by Latin American standards but is nonetheless higher than the actual growth rate in Cuba over the last decade of 0.28 percent. Finally, we calculate total primary energy consumption (TPEC) from total final (end-use) consumption (TFC) under the assumption that Cuba will gradually reduce energy transformation losses to 40 percent in 2015, 35 percent in 2020 and 30 percent in 2025. That would place Cuba in a position in 2025 roughly where Costa Rica, the Dominican Republic, and Guatemala were in 2006. We show a second set of calculations of energy demand if transformation losses are not reduced, to highlight the influence of transformation efficiency on energy demand. In this case, we assume that efficiency losses will continue into the future at 42 percent, the average level prevailing during the five-year period from 2002 to 2006.

The estimates from the two methods are reasonably consistent with one another. At a 3 percent rate of growth TPEC would be between 11.1 and 12.3 thousand ktoe by 2020 and between 10.2 and 11.3 thousand ktoe by 2025. Demand drops slightly, even though per capita income increases, because of assumed increases in efficiency. At a 5 percent growth rate, demand will be between 11.8 and 12.2 thousand ktoe by 2020 and 12.8 by 2025.

Taking the average of the high and low estimates for each case, we generate demand in terms of barrels of oil equivalent per day as follows: At a 3 percent growth rate demand will be 202,000 barrels of oil equivalent a day in 2020 and 207,000 by 2025. At a 5 percent growth rate demand would be 186,000 and 221,000 barrels a day, respectively. For comparison purposes, TPES in 2006 was 10,639 ktoe, the equivalent of 184,000 barrels a day. Future energy demand will increase by less than 25,000 barrels per day by 2025 at a per capita growth rate of 3 percent per annum and by about 37,000 barrels per day at a 5 percent growth rate. The assumption of reducing transformation energy losses is critical. If losses continue at the average level prevailing from 2002 to 2005, total demand in 2025 will be higher by 2,648 ktoe, or about 45,000 barrels per day, at 5 percent per capita growth.

Supply

As pointed out earlier, the U.S. Geological Survey has estimated that Cuba has mean "undiscovered" reserves of 4.6 billion barrels of conventional oil and 9.8 trillion cubic feet of gas in the North Cuba Basin. The USGS defines "undiscovered recoverable reserves (crude oil and natural gas)" as "those economic resources of crude oil and natural gas, yet undiscovered, that are estimated to exist in favorable geologic settings."[25] Recovery of these deposits is

technically feasible, given current technology, but not necessarily economically feasible, since feasibility will depend crucially on oil prices as well as production costs. The USGS develops a probability distribution of these potential reserves. Its high estimate puts them at 9.3 billion barrels of oil and 21.8 trillion cubic feet of gas. Cupet claims the country has 20 billion barrels of recoverable oil in its offshore waters, and asserts that the higher estimate is based on new and better information about Cuba's geology than that reported by the USGS.[26]

The translation of estimated reserves into projected annual production flows is very difficult, and depends on a large number of factors. Of great importance is the issue of how much of the technically recoverable reserves are economically recoverable. This will be determined by future technological developments as well as prices of oil and the inputs required to develop and produce the oil. The flow rate will be determined in part by the nature of the geological structure of any find and the size and distribution of deposits within it. Absent knowledge of these variables, forecasts of supply are at best illustrative.

However, given our demand estimates, an average production of 200,000 barrels a day is all that Cuba needs to become self-sufficient in energy use under most of our assumptions. If reserve estimates were to be realized, this production level would be a very conservative estimate of possible production flows. In chapter 2 of this volume, Jorge Piñón states that Cuba's heavy oil production potential in onshore and coastal offshore areas *alone* could "grow to an amount in excess of 75,000 barrels per day" once Cuba gains access to technology and capital. If this forecast is borne out, Cuba would need only 125,000 barrels per day from offshore areas to be self-sufficient. Elsewhere, Piñón has suggested that Cuba could produce as much as 525,000 barrels per day when deepwater reserves are developed.[27]

In the case of gas, Peter Hartley and Kenneth Medlock have developed the Rice University World Gas Trade Model, which estimates production around the world on the basis of projections of demand and costs of production, and transport. The model forecasts that Cuba's natural gas production could rise rapidly and average more than 150 billion cubic feet per year.[28] On a barrel of oil equivalent basis, this would amount to roughly 77,000 barrels per day.

Cuba's Ethanol Potential

It is natural to associate Cuba with sugar. At one time, Cuba was the world's largest exporter of sugar. It was a major supplier to the United States before the Cuban Revolution, and to the Soviet Union in the 1970s and 1980s. But

the industry has undergone a steep decline since major trade with the Soviet Union ended. Sugar production, as high as 8.1 million tons in 1988, had fallen to 1.25 million tons by 2009.[29] Acreage devoted to sugar was reduced by over 60 percent from 2002 to 2008. Sugar mills have been closed, with the number of plants falling from 156 to only 85. In 2006, output of raw sugar was approximately 1.2 million tons, reportedly the lowest output since 1908.[30]

Oddly enough, the retreat of the Cuban sugar industry has occurred at a time when many countries have been adopting policies to add ethanol, which can be made from sugarcane, to their transportation fuel portfolio. Despite the fact that Cuba is dependent on oil imports and is aware of the demonstrated success of Brazil in using ethanol to achieve energy self-sufficiency, it has not embarked on a policy to develop a larger ethanol industry from sugarcane.

In response to recent increases in ethanol prices, there is some support in Cuba for increasing ethanol production. A member of the Cuban Academy of Sciences, Conrado Moreno, has indicated that there are plans to upgrade eleven of the seventeen Cuban refineries to add annual production capacity of as much as 47 million gallons.[31] It remains to be seen whether this will happen without the support of top administration officials, especially Former President Fidel Castro.

Castro has rightly pointed out that there can be a direct trade-off between using land for food production and for ethanol. And in many areas of the world, the shift in land use to crops for ethanol has resulted in rapidly rising costs for food. There are also trade-offs between increasing acreage devoted to crops for ethanol and other objectives such as issues related to climate, environment, and biodiversity. In Brazil, for example, increasing acreage under sugarcane cultivation has resulted in shifting other crops to newly cleared areas, often in the rainforest, a process that ultimately could have devastating effects on climate and biodiversity within and beyond Brazil.

Cuba, however, has had a traditional comparative advantage in the production of sugar. Although some of the land used for sugar in the past is being shifted to food crops and reforestation, much of it is not currently being cultivated at all. Thus, for Cuba a restoration of the sugar economy does not necessarily have to involve environmental and food production trade-offs.

A Brief History of Sugar Cultivation in Cuba

Commodity markets are notoriously volatile and countries dependent on one or two commodity exports have always been subject to particularly harsh

swings in economic activity. Cuba, traditionally dependent on sugar exports, has fitted into this pattern. Cuba's membership in the CMEA (Council for Mutual Economic Assistance), the trade area set up by the USSR for trade among Communist states, provided temporary stability for sugar prices in the 1980s, but ultimately the political changes in 1989 once again subjected Cuba to the vagaries of market fluctuations in sugar prices.

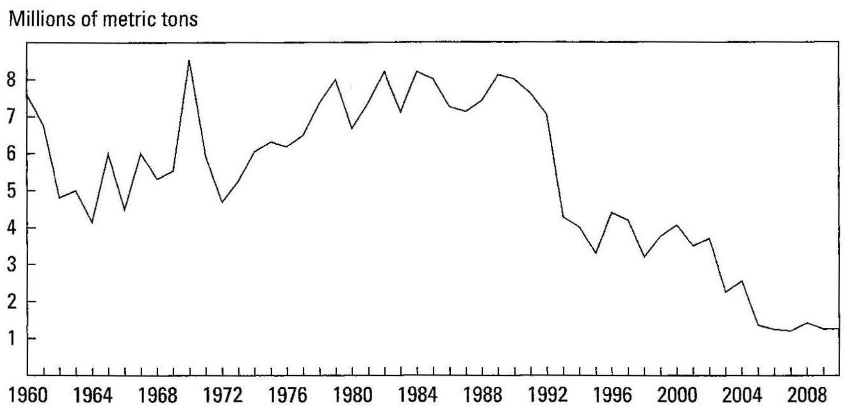
The heyday of the Cuban sugar economy was in the first three decades of the twentieth century, when sugar output increased fivefold, from less that 1 million tons in 1895 to 5.4 million tons in 1929.[32] Producing roughly 23 percent of the world's sugar (cane and beet sugar) and 36 percent of the world's cane output, Cuba was the world's largest producer and exporter of sugar.[33]

Cuban sugar production then declined to 2.1 million tons by 1932, in response to the worldwide depression and the imposition of the Smoot-Hawley tariffs in 1930 by the United States, Cuba's most important export market. Prices had already fallen by 38 percent between 1927 and 1929; by 1932 they had fallen an additional 57 percent, reaching the lowest level in the pre–World War II period.[34] Cuban sugar producers were further injured by the addition of U.S. sugar quotas in 1934 that favored producers in Hawaii, Puerto Rico, and the Philippines and limited Cuban exports to the United States to levels below those prevailing in the 1920s.[35]

During World War II, sugar production and exports recovered in tandem with the U.S. economy. After the war, international sugar agreements were implemented that helped stabilize prices by limiting world production. Cuban production came back to over 5.6 million tons by 1950, roughly where it was in the late 1920s, but exports to the United States were now governed by a system of tariffs and quotas. The dominant role of Cuba in international sugar markets and the inelastic demand for the product reduced the role of sugar as an engine of further growth and development in Cuba.

The postrevolutionary government chose to stress industrialization and agricultural diversification and to deemphasize sugar as its growth engine.[36] Alas, as many Latin American countries also discovered, an import substitution strategy requires ample supplies of capital and foreign exchange to finance investments in industry and the necessary complementary infrastructure, much of which has a large imported component. In the absence of private foreign investment, Cuba had to rely on its exports to provide the foreign exchange resources necessary for these investments. With sugar as its primary exportable commodity, Cuba's ambitions were quickly constrained by its loss of access to the U.S. sugar market once sanctions were imposed on the new regime.

Figure 4-1. Cuban Sugar Production, 1960 to 2010



Source: U.S. Department of Agriculture, Foreign Agricultural Service, "Production, Supply and Distribution Online" (www.fas.usda.gov/psdonline/psdQuery.aspx).

Sugar resumed its dominant role in 1963, when Cuba entered into a trading relationship with the USSR and Eastern Europe whereby Cuba was to become the major sugar supplier to these countries. Cuba launched an ambitious plan to produce 10 million tons by 1970, but actual production fell far short of this target despite a focused effort by the government. Still, Cuba produced 8.5 million tons of sugar, the highest production level ever achieved.

When Cuba formally joined the Council for Mutual Economic Assistance (CMEA) in 1972, it did so under a generous arrangement with the USSR, which was prepared to pay Cuba a sugar price that was substantially higher than international market prices. The success of this arrangement for Cuba is apparent in the statistics for Cuban sugar production (see figure 4-1). Production grew rapidly and fluctuated between 7 million and 8 million tons during the 1980s.[37]

The collapse of the Soviet Union and the CMEA trading bloc was a disaster for the Cuban sugar industry. Once the lucrative communist bloc agreement that had provided stability was ended, Cuba was faced with global competition. However, years of high prices and the absence of competitive pressures had resulted in a loss of efficiency which, in combination with other problems faced by the agricultural sector in general, led to a period of continuous decline for the industry.

In 2002 the Cuban government launched a major restructuring of the sugar sector: sugarcane acreage was severely reduced and of the 156 sugar

mills that existed at that time, 71 were closed permanently, 14 were devoted solely to the production of molasses and raw sugar for animal feed, and 64 were dismantled to be used as spare parts for the remaining mills.[38]

These reforms had a major impact on employment and resulted in the migration of farm labor to urban areas. Estimates of displaced workers range from 100,000 to 213,000 out of the 400,000 previously employed in the industry.[39] The policy's intention was to maintain sugar output at 4 million tons, but announced targets were not met. Like other areas of the economy, the sugar industry was plagued by aging plants and equipment and a lack of spare parts for maintenance. As of 2005, writes Carmelo Mesa-Lago, "only 70 percent of the mills operated and [these] were affected by frequent breakdowns."[40] In addition, the scarcity of foreign exchange limited imports of fertilizer and other supplies for the industry. Cuba actually had to import sugar in order to meet domestic demand and its export commitments to China. The situation prompted President Castro, reflecting frustration with the failure of the industry to meet targets, to say, "Sugar belongs to slavery times and will never come back to this country." Disillusionment with the sugar industry lies behind Castro's lack of support for the development of an ethanol industry.

Cuba's Future Sugar Industry: Ethanol Scenarios

The success of the Brazilian sugarcane and ethanol industry suggests that, despite former President Castro's views on the impossibility of restoring a viable Cuban sugar industry and the impact of sugar cultivation for ethanol production on food supplies, the Cuban sugar industry could have a promising future. The increasing use of biofuels in the transportation fuel mix in the United States and Europe provides a stable and growing market for ethanol, especially sugarcane-based ethanol, which is cheaper to produce than biofuels from other crops. The United States, under the Energy Independence and Security Act of 2007, increased the renewable fuels standard (RFS) to require that the use of biofuels gradually increase, to 36 billion gallons by 2022. Legislators intended that 16 billion of this consumption would come from cellulosic ethanol, but so far the development of a cost-effective production technology has been slow, leaving the market to corn- and sugar-based ethanol.

In 2009 the U.S. consumed 11.1 billion gallons of ethanol, almost all of it produced in the United States. U.S. policy favors domestic ethanol production by imposing an import tariff of 54 cents a gallon in addition to a

2.5 percent ad valorem tariff. Tariffs have limited ethanol imports into the United States, but higher prices in Europe have also been a factor. As of 2009, the United States has been suffering from an excess of production capacity, which has depressed prices in the States relative to other importing countries. But as higher U.S. renewable fuel targets kick in and U.S. prices recover from overinvestment in capacity, imported sugar-based ethanol will be competitive with higher-cost U.S. corn-based ethanol in coastal regions of the United States, even if U.S. tariffs persist. Given the high costs to transport corn-based ethanol to coastal regions from the U.S. Midwest by rail or truck.[41] Cuba's location gives it a large transport cost advantage over both domestic and foreign rivals.

Our analysis suggests that Cuba can produce 2 billion gallons of ethanol per year, equivalent to 94,500 barrels per day of gasoline, after adjusting for the differences in energy content. To arrive at this estimate we consider several factors that help determine ethanol output:

—The amount of land planted with sugarcane

—Yields (the amount of sugarcane harvested per hectare planted)

—The industrial yield (the amount of ethanol that can be produced from one ton of sugarcane)

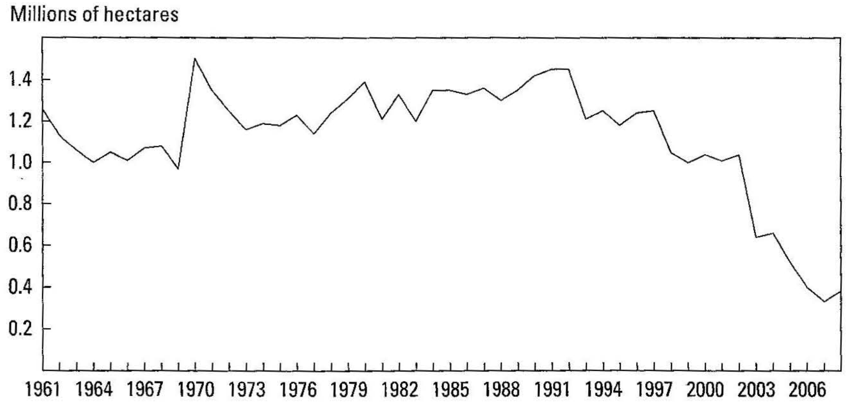
—The proportion of sugarcane devoted to the production of sugar and other non-ethanol products

Amount of Land Planted with Sugarcane

Figure 4-2 shows the area of sugarcane harvested each year from 1961 to 2008. In 1970, the year of the ambitious campaign to produce 10 million tons of sugar, the area harvested was 1.5 million hectares, the highest level in the post–World War II period. Between 1971 and 1989 the area harvested averaged 1.28 million hectares, fluctuating between 1.14 million and 1.42 million hectares. After the collapse of the USSR and the end of Soviet aid, the harvested area plummeted, reflecting at first the decline in imported fuel, fertilizer, and other inputs and later, the decision to restructure the industry by shutting down inefficient sugar refineries and switching farms to pasture or other crops.

Since the special period in the early 1990s, Cuba has moved to diversify its agricultural sector in order to emphasize food security. It's not clear whether this was a response to economic and political conditions at the time or represents a permanent shift of agriculture away from depending so heavily on

Figure 4-2. Amount of Land Planted in Sugarcane, 1961 to 2007

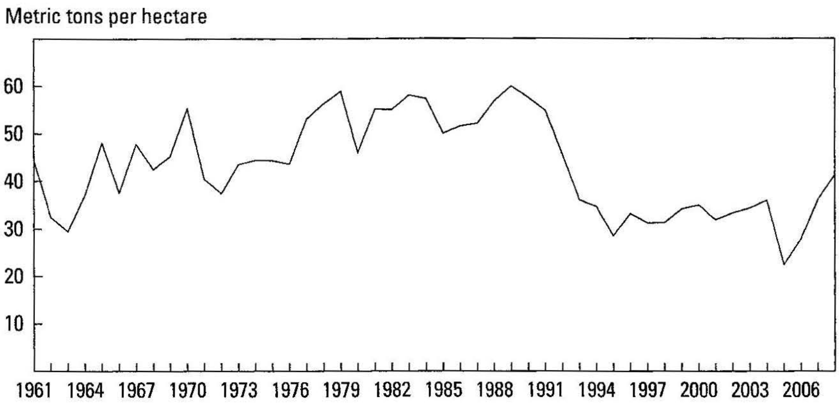


Source: Food and Agriculture Organization of the United Nations (http://faostat.fao.org/site/567/Desktop Default.aspx?PageID=567#ancor).

one crop. More recently, in 2008, the Cuban government announced grants of unused land to all private, cooperative, and state farms, as a spur to enhance domestic food production. The introduction of the plan was a response to the fact that in 2007, 55 percent of agricultural land remained idle, an increase from 46 percent in 2002.[42]

The shift in acreage devoted to food crops has not been successful in terms of increasing food output,[43] but reforms to give farmers more discretion in how they operate might produce better results in the future. But significantly increasing acreage devoted to food crops will not be easy. Food crops are much more fragile than sugarcane, requiring more labor, weeding, pest control, and oversight than cane, which has been referred to as the "widow's crop" because it requires relatively little attention. As noted previously, thousands of farm workers have migrated to urban areas and it will be difficult to lure them back. If economic sanctions are removed and Cuba enters the international commercial system, food security will be less important, and Cuban agriculture will be more likely to respond to international prices. Historically, Cuba has had a comparative advantage in producing sugar, not food crops; so opening the economy to freer trade might favor a return to the dominance of sugar and development of an ethanol industry. More recently, Cuba has expressed interest in producing and

Figure 4-3. Total Cuban Sugarcane Yields, 1961 to 2007



Source: Food and Agriculture Organization of the United Nations (http://faostat.fao.org/site/567/Desktop Default.aspx?PageID=567#ancor).

exporting soybeans, and the Brazilian government has offered "technical assistance and seed in order to grow soybeans on an industrial scale."[44] Soybeans have many uses, including as a feedstock for the production of biodiesel, but it is not clear at this point whether soybeans represent a more efficient use of Cuban land than sugarcane.

Sugarcane Yields

Sugarcane yields are highly variable—affected by weather conditions and other factors. Figure 4-3 shows sugarcane yields since 1961 and the decline in recent years as the industry has contracted. Yields that had fluctuated between fifty and sixty tons per hectare fell to twenty-eight in 2006.

Industrial Ethanol Output Levels

Table 4-5 shows the level of ethanol output per hectare of land that is devoted to the production of sugarcane targeted for ethanol production. Output in liters is shown as a function of sugarcane and distillery yields.

At a sugarcane yield of 75 tons per hectare and ethanol yield of 75 liters per ton (5,625 liters per hectare), an output of 7.6 billion liters, or 2 billion gallons, of ethanol requires approximately 1.33 million hectares of sugarcane. At 80 tons per hectare, it would require only 1.26 million hectares to produce 2 billion gallons. Finally, if Cuba achieves yields currently experienced in the Center-South region of Brazil of 84 tons per hectare and 82 liters per ton of

Table 4-5. Ethanol Output
Liters per hectare of sugarcane

		Sugarcane yield (metric tons per hectare)					
		32.3	55	75	80	85	90
Distillery yields (liters/ton)	70	2,261	3,850	5,250	5,600	5,950	6,300
	75	2,423	4,125	5,625	6,000	6,375	6,750
	80	2,584	4,400	6,000	6,400	6,800	7,200

Source: Authors' calculation.

cane (6,888 liters per hectare), it will need only 1.10 million hectares of sugarcane to achieve this volume.[45]

Sugar versus Ethanol

The amount of ethanol produced will also depend on how much of the sugarcane is used to produce sugar and other non-ethanol products. In 2009 Cuba produced 1.25 million metric tons of sugar on 380,000 hectares with very low yields of 41.3 tons per hectare. At an improved yield of 75 tons per hectare, 1.25 million tons of sugar would have required only 209,150 hectares, which at 5,625 liters of ethanol per hectare, would reduce ethanol output by 1,175,625 liters (310,000 gallons).

Sugar prices rose very quickly in 2009 to levels that are high by historical standards, approaching 25 cents a pound.[46] At these prices, producing and exporting sugar is more attractive than ethanol. But these prices are the temporary consequence of bad weather in other sugar-producing areas and will not be sustained. Both sugar and ethanol are commodities that will trade on the basis of price, and since entry into those industries is relatively unconstrained, competition will push prices down toward costs. When sanctions are lifted. Cuba will be able to benefit from the fact that it is an island economy with easy access to cheap marine transport—and the close proximity to the United States. Sugar imports in the United States are limited by quotas, so import volumes cannot change regardless of price. However, ethanol is protected by tariffs so imports can increase if domestic (U.S.) prices get too far ahead of world prices.

The fact that sugar exports are an alternative to ethanol is an additional argument for the development of an ethanol industry. To the extent that sugar and ethanol prices are not closely correlated, Cuba can alter its output mix between the two products to take advantage of variations in sugar and ethanol prices and thus smooth out fluctuations in export revenues as well as maximize the income from its sugarcane industry.

Issues in Achieving Cuba's Ethanol Potential

As noted, estimates of Cuba's ethanol potential will depend on assumptions about the amount of sugarcane that can be planted and harvested, as well as what sugarcane yields can be achieved. More ambitious assumptions will yield higher outputs. For example, Juan Sanchez assumes that Cuba could devote 2 million hectares to sugarcane with yields of 80 tons per hectare and 83.6 liters per ton (6,688 liters per hectare). He projects ethanol output at 13.4 billion liters, or 3.5 billion gallons.[47]

Three and a half billion gallons seems unrealistic for the foreseeable future. There is some question as to whether Cuba could ever again attain the 1.5 million hectares of sugarcane harvested in 1970, let alone 2 million. According to Brian Pollitt, the 1970 harvest was achieved only by cutting cane that would normally be left to mature for another season in order to produce a higher sugar yield in the following year.[48] Obviously this is not a sustainable practice if optimal yields are to be achieved.

Two billion gallons can be produced with a harvested area of 1.33 million hectares and a yield of seventy-five tons per hectare. That area of cultivation is not too far from the average harvest of 1.28 million hectares that Cuba was able to maintain during the 1970s and 1980s. Yet reaching 1.33 million hectares will require time and substantial investment in farm machinery and restoration of the land, which has been neglected and compacted by the use of heavy Soviet-built harvesting machinery. The land will also have to be tilled and newly planted with sugarcane.

Achieving higher sugarcane yields will also require time and investments to acquire or develop higher-yielding sugarcane varieties. Cuban yields averaged only fifty-eight tons per hectare during the 1970s and 1980s, substantially below the seventy-five tons per hectare needed to produce 2 billion gallons of ethanol. Yet other countries, as noted, have achieved or exceeded that yield, and some private Cuban farmers are reported to have achieved even higher yields of 100 tons per acre.[49] Yields, of course, are a function of other factors besides cane variety. The condition of the land, access to water and fertilizer, and other inputs would all need to be considered.

Finally, Cuba will have to undertake significant investments in distilleries, transport, storage, and distribution infrastructure if it wants to produce the levels of ethanol that the authors believe are achievable. Investment costs for the biorefineries alone will come to billions of dollars. For example, in 2006, corn-based ethanol plants in the United States cost roughly $1.88 per gallon for a capacity of 48 million gallons per year, and $1.50 per gallon for capac-

ity of 120 million gallons per year (reflecting significant economies of scale). So even if all new plants in Cuba were built with the larger capacity, it would require $3 billion dollars (at 2006 prices) to build sufficient capacity to produce 2 billion gallons.

Looking at the Brazilian experience with ethanol is instructive. There, in 1975, the government introduced Proálcool, its national ethanol-production program, as a response to the oil shocks of that decade. It took several decades for Brazil to achieve current agricultural yields and ethanol output. Its approach to promoting ethanol use was to mandate that gasoline be mixed with 10 percent ethanol starting in 1975 and that this proportion should be increased to 25 percent by 1980. The government provided loans for the construction of ethanol plants and guaranteed the price of ethanol. Following the second spike in the price of oil in 1980, the government required Petrobras, the state-owned oil company, to supply ethanol to filling stations and offered a subsidy to auto firms to produce cars that could run on pure ethanol. It is estimated that the government spent over $16 billion (in 2005 dollars) between 1979 and the 1990s on subsidies and price supports to promote the industry.[50]

Cuba has the advantage of being able to learn from the Brazilian experience, even though the evolution of the industry in Cuba will certainly differ from that in Brazil. Exports could play a larger role at an earlier phase in the development of the Cuban industry. Domestic absorption of ethanol within Cuba will be constrained by the longevity of the existing vehicle stock (which burns only gasoline), the speed with which the number of motor vehicles is increased, and the extent to which new vehicles are "flexfuel" vehicles, able to burn both fossil and biofuels. Cuba has the additional advantage of a more robust international demand for ethanol than was the case when Brazil initiated its policy thirty years ago.

Cuba has opened the door to foreign investment in the ethanol sector, and Brazil has expressed interest in sharing its expertise in order to promote the use of ethanol and the development of a market where ethanol is traded like other commodities.

Ethanol and the Production of Electricity

The economics of ethanol production from sugarcane is enhanced by using the sugarcane waste (bagasse) to produce electricity by burning it. One estimate is that Cuban mills produce 20 and 40 kilowatt-hours per ton of sugarcane, depending on the age and efficiency of the steam turbines.[51] This is below the 55 kilowatt-hours reported for plants in Central America and

significantly below the 100 kilowatt-hours per ton achieved by some Hawaiian mills.[52] Although bagasse is available only during the harvest season, these plants can be fueled with woodchips and other waste in at least part of the non-harvest season. Even at the modest yield of 55 tons of sugarcane per hectare and 55 kilowatt-hours per ton, a million hectares of sugarcane will produce roughly 3 billion kilowatt-hours of electricity, almost 20 percent of the 16.5 billion kilowatt-hours produced in Cuba in 2006. With higher yields, 1.3 million hectares could produce 4 billion to 5 billion kilowatt-hours.

The Structure of an Ethanol Industry

If Cuba decides to develop an ethanol industry it will have to decide on how to structure it. In particular, it will have to decide on the relative roles of the Cuban state and private citizens as well as the role of foreign companies.

There are several models that Cuba can choose from. One is to resuscitate a national, state-owned sugar industry with the addition of state-owned biorefineries. Sugarcane would be grown on state farms and cooperatives, processed in state-owned biorefineries, and marketed by an agency of the government. Past experience suggests that the state has not been able to operate the sugar industry in a cost-competitive way. Recent land reforms are motivated by that experience. Agriculture depends on rapid decisionmaking in response to changing location-specific information such as weather patterns, soil conditions, and pest infestations. Successful agriculture depends on decentralized decisionmaking with proper incentives given to the decentralized manager, a lesson learned in all highly centralized economies. In addition to these efficiency considerations, the Cuban government would have great difficulty in raising the enormous amounts of capital necessary to revive large-scale sugar cultivation and construct biorefineries and other needed infrastructure if these were to be solely within the state sector.

Another option is to follow the policies used in the oil and nickel industries, where foreign private firms currently operate. These firms provide the technology, management expertise, and capital, while the state provides labor. Workers would have to be well paid and well treated—otherwise this approach might be politically difficult, since it would hark back to the sugar plantations of the prerevolution years. Under this model Cuba is able to get access to needed resources, yet still maintain "control" of the industry and the egalitarian income policies that characterize the Cuban socialist model.

Finally, Cuba can continue its agricultural reforms and encourage sugarcane cultivation by individual farmers or cooperatives who could sell their output to biorefineries owned and operated by privately owned domestic

or foreign firms. This option might attract foreign capital and expertise in the biorefinery end of the industry, but it is difficult to see where private and cooperative farms would get access to the large amount of capital needed to rebuild the agricultural capacity of the country. Farmers would require access to credit to purchase inputs needed in the cultivation of sugarcane. In the absence of U.S. sanctions, Cuba would have access to the resources from the international banking institutions (World Bank and the Inter-American Development Bank), but resources from these institutions come with controls and constraints that the Cuban government would find uncomfortable. Furthermore, relying on more independent farmers would also create a class of private and cooperative farmers whose incomes would not be subject to state control, and could lead to income inequalities.

Conclusion

Our intention in this chapter was to present the case that Cuba's energy potential is sufficient for Cuba to shift from its status as a net importer of roughly 100,000 barrels of oil a day to one of a net energy exporter. We have derived what we feel are conservative estimates of future energy demand and suggest that Cuba's oil production potential alone could probably satisfy future energy demand growth, provided that Cuba begins to do something about its abnormally high energy transformation losses. In addition, we suggest that Cuba could produce upwards of 150 billion cubic feet per day of natural gas, equivalent to 77,000 barrels of oil equivalent per day. Finally, ethanol production of 2 billion gallons per year could replace 94,500 barrels per day of gasoline as well as 3,000 gigawatt-hours of electricity—18 percent of current Cuban production—through cogeneration.

It is not possible to generate estimates of Cuban demand for specific fuels, since Cuba will have a choice of which to use domestically and which to export, depending on the relative prices of various fuels in international markets. But it is clear that Cuba has the potential of being a significant exporter of several energy resources, shifting the country from a nation where energy poverty has negatively affected overall economic performance to a country where energy surpluses could support economic growth.

The development of its energy resources could have a profound impact on Cuba's economy. Simply replacing current oil imports would release foreign exchange for other developmental uses. For example, at $60 a barrel, 100,000 barrels per day of imports has a market value of $2.2 billion a year, roughly equivalent to all the earnings from the tourist industry.[53] Energy

exports will add a further significant boost to the Cuban economy. The experience of Brazil is instructive. In the 1970s Brazil found itself facing financial crises when oil prices spiked as a result of Middle East instability. By contrast, Brazil in 2007 and 2008—by then a net exporter of energy—saw less economic hardship arising from the dramatic increase in oil prices than other industrialized countries in those years.

Whether the scenarios discussed in this chapter are realistic can be established only when serious oil and natural gas exploration and development of Cuban assets begins. Cuba's nascent potential in ethanol also remains theoretical so far. However, the recent political transition in Cuba and the change in administration in the United States make this an ideal time to reevaluate U.S.-Cuba policy, taking into consideration humanitarian issues as well as energy potential. Having an additional supplier of energy to the U.S. market from only a few miles off shore can only contribute to the United States' energy security.

Notes

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3. David R. Mares and Nelson Altamirano, "Venezuela's PDVSA and World Energy Markets: Corporate Strategies and Political Factors Determining Its Behavior and Influence," *The Changing Role of National Oil Companies in International Energy Markets* (Houston: Rice University, James A. Baker III Institute and Japan Petroleum Energy Center, 2007).
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5. Central Intelligence Agency, *The World Factbook*, "Cuba" (www.umsl.edu/services/govdocs/wofact2006/geos/cu.html#Econ; www.umsl.edu/services/govdocs/wofact2007/geos/cu.html#Econ; www.cia.gov/library/publications/the-world-factbook/geos/cu.html).
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13. "Oil and Gas—Cuba," Sherritt.com (www.sherritt.com/doc08/subsection.php?submenuid=operations&category=operations/oil_and_gas_cuba).

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18. International Energy Agency, Energy Balance Spreadsheet (www.iea.org); they may differ from other estimates. The term "energy balances" is standard usage (by the IEA and others) to depict data on energy supply and demand and their components—domestic production, imports and exports, and consumption.

19. Marcus Enoch and others, "The Effect of Economic Restrictions on Transport Practices in Cuba," *Transport Policy* 11, no. 1 (January 2004): 67–76.

20. Mesa-Lago, "Cuban Economy in 2004–2005."

21. Kenneth Medlock III and Ronald Soligo, "Economic Development and End-Use Energy Demand," *Energy Journal* 22, no. 2 (April 1, 2001): 77–105.

22. The Cuban per capita income statistic, $8,172, given in the IEA database (subscription database) is unrealistically high. Consequently, the authors have used the number $4,100, given in Central Intelligence Agency, *World Factbook* 2006 (www.umsl.edu/services/govdocs/wofact2006/geos/cu.html).

23. There is no consensus on the level of Cuba's per capita income. The per capita income in 2000 PPP (purchasing power parity) dollars given in the most recent IEA data (subscription online database) is roughly twice that reported in earlier versions based on 1995 dollars. The difference in the two series cannot be accounted for by

inflation in that short period. Mesa-Lago ("Cuban Economy In 2006–2007") has shown that when Cuba changed the base year used to estimate GDP in constant dollars from 1981 to 1997, reported GDP increased by 56 percent on average for each year from 1989 to 2000 and per capita income by 85 percent for 2001! In addition, Cuba introduced a new national accounting methodology in 2003 that had the effect of further increasing GDP. For our purposes the precise measurement of per capita income is not critical.

24. For example, the oil price forecast of the U.S. Department of Energy's Energy Information Administration (EIA) in its 2009 Annual Energy Outlook, "World Oil Prices in Three Price Cases 1980–2030" (www.eia.doe.gov/oiaf/ieo/graphic_data_world.html), assumes that prices, in its reference case, will rise in real terms to $121 per barrel by 2025, and total primary energy demand will only be 10,425 ktoe in 2020 and 10,531 ktoe in 2025 at a 5 percent growth rate in per capita income. This is in contrast to 12,165 and 12,799, respectively, with $55 per barrel oil, figures arrived at by means of simulations done with the Medlock-Soligo model discussed in the text.

25. U.S. Energy Information Administration, "Glossary—U" (www.eia.doe.gov/glossary/glossary_u.htm).

26. Jeff Franks, "Cuba Says May Have 20 Billion Barrels of Oil Offshore," Reuters, October 16, 2008.

27. For comparison, Equatorial Guinea currently produces approximately 400,000 barrels per day with proven reserves of 1.2 billion barrels in deep water offshore. If Cuba's offshore resources are comparable, 525,000 barrels per day is not an unreasonable estimate.

28. Production estimates were provided by the authors of the model. For a discussion of the model see Kenneth Medlock and Peter Hartley, "Rice University World Gas Trade Model," CEC Workshop Presentation, June 16, 2009 (www.energy.ca.gov/2009_energypolicy/documents/2009-0616_workshop/presentations/07_Medlock_The_Rice_World_Gas_Trade_Model.pdf).

29. U.S. Department of Agriculture, Foreign Agricultural Service, Downloadable Data Sets (www.fas.usda.gov/psdonline/psdDownload.aspx).

30. Marc Frank, "Cuba Plans Big Increase in Ethanol Production," Planet Ark website, June 21, 2006 (www.planetark.com/dailynewsstory.cfm/newsid/36927/newsDate/21-Jun-2006/story.htm).

31. "Cuba to Modernize Its Ethanol Production," Oryza News (website on rice), May 23, 2007 (http://oryza.com/Global-Rice/Bio-Tech-News/Cuba-ethanol.html).

32. Brian Pollitt has provided a detailed history of the Cuban sugar industry: Brian H. Pollitt, "The Cuban Sugar Economy: Collapse, Reform and Prospects for Recovery," *Journal of Latin American Studies* 19 (1997): 171–210. See also Pollitt, "The Rise and Fall of the Cuban Sugar Economy," *Journal of Latin American Studies* 36 (2004): 319–48.

33. Pollitt, "Rise and Fall of Cuban Sugar Economy," 320.

34. Pollitt, "Cuban Sugar Economy," 172.

35. Pollitt, "Rise and Fall of Cuban Sugar Economy," 321–22.

36. See Jorge F. Pérez-López and José Alvarez, "The Cuban Sugar Agroindustry at the End of the 1990s," in *Reinventing the Cuban Sugar Agroindustry,* edited by Jorge F. Pérez-Lopez and José Alvarez (Lanham, Md.: Lexington Books, 2005), p. 27.

37. Production, acreage, and yield data: Food and Agriculture Organization of the United Nations (http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor).

38. Jorge F. Lopez, "The Cuban Economy in 2002–2003," *Cuba in Transition* 12 (2003): 507–21.

39. Ibid., 9.

40. Mesa-Lago, "Cuban Economy in 2004–2005," 7.

41. The Energy Forum of the James A. Baker III Institute for Public Policy and Rice University's Department of Civil and Environmental Engineering, "Fundamentals of a Sustainable U.S. Biofuels Policy," January 2010, p. 49 (www.bakerinstitute.org/publications/EF-pub-BioFuelsWhitePaper-010510.pdf).

42. Marc Lacey, "Cuba to Grant Private Farmers Access to Land," *New York Times,* July 19, 2008 (www.nytimes.com/2008/07/19/world/americas/19cuba.html).

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

44. Estaban Israel, "Brazil to Help Cuba Grow Soy on Industrial Scale," Reuters UK, May 30, 2008 (http://uk.reuters.com/article/idUKN3042480220080530).

45. Datagro (Brazil) Private communication with the authors.

46. Prices have continued to rise in 2010. See Index Mundi website, "Sugar Monthly Price" (www.indexmundi.com/commodities/?commodity=sugar).

47. Juan Tomás Sanchez, "Cuba y el Etanol: Proyeciones para una economía privada" [Cuba and ethanol: Projections for a private economy], *Cuba in Transition* 17 (2007): 199–205.

48. Pollitt, "Cuban Sugar Economy," 185.

49. Walfrido Alonso-Pippo and others, "Sugarcane Energy Use," 2168.

50. Estimate made by Datagro, reported by David Luhnow and Geraldo Samor, "As Brazil Fills Up on Ethanol, It Weans off Energy Imports," *Wall Street Journal,* January 16, 2006, p. A1.

51. These figures are for net export to the grid. See Roger Lippman and others, "Renewable Energy Development in Cuba: Sustainability Responds to Economic Crisis," April 1997 (http://tlent.home.igc.org/renewable%20energy%20in%20cuba.html).

52. Ibid.

53. Although Cuba is not currently paying market prices for its imports from Venezuela, it cannot assume that this favorable arrangement is permanent. Rather, Cuba should view Venezuelan aid as a bridge to the time when market prices will have to be paid.