Working Paper

Cuba's Response to Energy Crisis

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1. Introduction

Cuba is a small island country. It is not only a geographical island but also a politically isolated regime. This special geopolitical environment has exacted a harsh resource shortage from Cuba. If it had been hundreds years ago, Cuban people might have found a self-sustaining way using just domestic resources. From the beginning of 17th century until mid-19th century, Japan is said to have had sustainable society in its archipelago. During the time called 'Edo period', Japanese people were used to reusing and recycling almost everything. Energy resources were not an exception. Oil was made from sesame seeds. Woods consumption was just as much as the annual growth of forest biomass. (Japan for Sustainability, 2003) But that kind of life cannot be easily applied to the people living in modern world who are accustomed with far greater material consumption. Especially, energy is one of the most crucial material resources modern people depend on. Just a small reduction of energy supply might result in enormous change in everyday's life.

In this paper, I'll overview how Cuba was forced into energy crisis and how they have been dealing with the problem.

2. Cuba's Energy Famine

2.1. Causes

2.1.1. U.S. sanctions and embargo

The U.S. embargo of Cuba was initiated after Fidel Castro, the Cuba's president then and now, nationalized U.S. properties in Cuban territory in 1959. Cuba's pro-Soviet foreign policy that was mostly against the U.S. was one more reason of the embargo. But even after the Soviet Union was collapsed, the trade prohibition on Cuba has never been lifted. (Ratliff and Fontaine, 2000) Until 1990, however, the sanctions were not so effective as to break down Cuba's economy and overthrow its political stability. In 1988, Cuba was analyzed to be dependent 85% of its trade on the Soviet bloc. The Cuban Americans who left their home country to find

freedom and economic opportunity were also a strong financial support to Cuba by sending money to their families. (Askari, *et al*., 2003) So the U.S. government banned shipments of materials (clothes and hygiene articles) to relatives in Cuba and restricted visits to close family members in Cuba in 2004 (UN, 2006).

According to Cuba, the U.S. embargo has influenced on every aspects of its people (Table 1). Limited exports of products and services reduced Cuban people's income, the geographical advantage could not be taken, production and services were suppressed, technology could not be easily introduced from foreign countries, financing Cuba's economy was not easy, and many brains left the country.

Table 1. Direct damage caused by the United States embargo: Cumulative figures up to end 2005 (UN, 2006)

	Millions of dollars
Lost income from exports and services	39,427.5
Losses from geographical relocation of trade	19,592.0
Impact on production and services	2,866.2
Technological embargo	8,483.2
Impact on service to the population	1,565.3
Financial and monetary impact	8,640.2
Impact of brain drain	5,533.8
Total impact of United States embargo	**86,108.2**

2.1.2. Collapse of the U.S.S.R.

But with the opening of 1990's, Cuba's economy was severely blown to stagger by the sudden collapse of the Union of Soviet Socialist Republics and its satellite COMECON (Council for Mutual Economic Assistance) bloc, that is, the former Eastern European communism countries. Because they were the main source of trade and support, the shortage in Cuba's material supply was worsened than the time under the U.S. embargo alone (GEF, 2004a). Fidel Castro named the calamitous period from 1990 to 2000 "the Special Period in Time of Peace" (Maal-Bared, 2006: 350; "the Special Period" henceforth). During the Special Period, Cuban economy was in abyss and food and medical facilities were always insufficient, let alone energy resources. (Potterf, 2006)

2.2. Effects

According to Cuba, the U.S. embargo has influenced on every aspects of its people (Table 2)

Table 2. Trends of Cuban energy production, consumption, and imports since the Special Period (IEA, 2006a; IEA, 2006b)

Energy Source	Data	Trend
Energy, Overall	Total production of energy	has been steady since 1990.
	Total net imports of energy	were dropped down in 1995 and 2000 and has been steady since 1995.
	Total primary energy supply	was dropped down in 1995 and has been steady since then.
Oil	Production of crude oil, NGL, and additives	has been rapidly increasing.
	Net imports of crude oil, NGL, refinery feedstocks and additives	were dropped down in 1995 to almost one sixth of 1990 level and have not been recovered until 2004.
	Net imports of petroleum products	had been decreased since 2000 and has been recovered since 2003.
	Refinery output of petroleum products	was dropped down in 1995 to one third of 1990 level and has not been recovered until 2004.
	Production of petroleum products	was dropped down in 1995 to less than one third of 1990 level and has been steady since then.
	Industry consumption of oil	has been decreasing since 1990.
	Transport consumption of oil	was dropped down during 1990 and 1995 and has been steady since 1995 at less then one half of 1980 level.
	Final consumption of oil	was dropped down in 1990 and 1995 and has been steady since 1995.
	Primary supply of oil	was dropped down in 1995 and has been steady since then.
Coal	Industry consumption of other bituminous coal	was dropped down in 1995 and 2000 and has been steady since 2000 at one tenth of 1990 level.
	Final consumption of other bituminous coal	was dropped down in 1995 and 2000 and has not been recovered until 2004.
Natural Gas	Production of natural gas	has been rapidly increasing.
	Primary supply of gas	has been steadily increasing since 1995.
Electricity	Production of electricity from fossil fuels	has been gradually increasing.
	Production of electricity from combustible renewables and waste	has peaked in 1990.
	Consumption of electricity	has been slowly increasing.
	Industry consumption of electricity	was dropped down in 1995 has been steady since then.
	Total production of electricity	has been steady since 1990 around 15,000-16,000 GWh.
Renewable Energy	Production of combustible renewables and waste	has been gradually decreasing since 1990.

The effects of the two causes on Cuba's energy section were collected in Table 2. Almost every figure of the energy production, consumption, and imports was cut down in 1990. Since 1990, there has been no sign of full recovery, either. The worst energy famine seems to be in 1995. Net oil imports, oil consumption, coal consumption, and industrial electricity consumption were dropped down in that year. Above all, per capita energy supply shows how severe Cuba's energy crisis is (Table 3).

Table 3. Total Primary Energy Supply (TPES) per capita in Cuba (IEA, 2006a)

Year	1971	1973	1980	1990	1995	2000	2002	2003	2004
TOE per Capita	1.27	1.33	1.55	1.59	0.96	1.03	0.96	0.94	0.95

3. Efforts to Overcome the Energy Famine

3.1. Fossil Fuel and Nuclear Energy – More Resources or Less Consumption

Oil is the foremost resource for Cuba's energy supply. Petroleum supplied 71.9% of Cuba's total primary energy consumption in 2001 (Alhajji and Maris, 2005).

After oil imports from the Soviet bloc were reduced significantly, Cuba's domestic oil reserves have received renewed interests. Geologically, Cuba has two basins that is proven or considered highly probable to have economic reserves of crude oil: the Florida-Bahamian Plate and the Caribbean Plate. Between the two basins, the Florida-Bahamian Plate is analyzed to be economical. The Cuban government enacted a Production Sharing Agreement to attract foreign oil companies' investment. Foreign companies explore possible oil reserves on their own expenses. When they find a commercially profitable reserve, their costs are recovered and they share additional profits with the Cuban government. Thanks to the exploration of foreign (mostly Canadian) companies, crude oil production in Cuba soared to 73,500 barrels per day in 2004 from 18,000 in 1992. (Piñón Cervera, 2005) Because even the U.S. Geological Survey estimated the probability of new oil reserve in the North Cuba Basin as 95% (USGS, 2005), Cuba will have more opportunity to exploit their deep ocean oil fields.

Foreign oil has been newly imported, in the middle of the U.S. sanctions. Even during the Special Period, Russian oil was bartered for Cuban sugar, although the amount has precipitously dropped after the Soviet collapse (Alonso and Galliano, 1999). It was a neighboring country who endowed a big relief to Cuba's energy crisis. Since 2000, Venezuela agreed to supply its crude oil to Cuba, requiring substantially long repayment period. The amount was allegedly nearly 85,000 barrels per day. (Benjamin-Alvarado, 2006) Because the oil deficit of Cuba in 2002 was assumed to be 100,000 barrels per day, this agreement was fairly beneficial to Cuba. (Piñón, 2004) Venezuela's generosity toward Cuba went further. In 2005, Venezuela decided to offer additional oil in exchange for Cuban medical personnel (Linger, 2006). Crude oil imports from Venezuela are now estimated 98,000 barrels per day (Pérez-López, 2006).

Currently, since the Special Period, Cuban oil refinery facilities have not been upgraded. With low efficiency and heavy pollution, those old facilities are imposing a barrier to Cuba's oil ambition. (Piñón Cervera, 2005) But recently, Venezuela agreed to help Cuba refurbish one of the old refinery. The refinery will process Venezuelan crude oil. (Ritter, 2006)

Because Cuba has no coal, the country will have to use natural gas to generate electricity. As a part of efforts to address this problem, Cuba found a joint venture with a Canadian company in 1997 to supply natural gas that is usually comes from oil reserves. (Alhajji and Maris, 2005)

Because the Cuba's oil reserves are assessed to be very promising, its associated natural gas is estimated economical. Some analysts are proposing a possibility of exporting Cuban natural gas to Florida by pipeline (Jaffe and Soligo, 2000).

Nuclear energy was another option for Cuba. Since late 1970's Cuba had tried to build two nuclear power reactors. However, in 1992, the plan was declared in suspension, mainly due to no more financial support from the Soviet Union. The CEN Juraguá reactor No. 1 has been left out as 14 to 92 percent of its civil or mechanical construction processes is completed. (Benjamin-Alvarado, 1996)

3.2. Energy Savings and Energy Efficiency

Before the collapse of the U.S.S.R., Cuba was not so different from former communist countries in Eastern Europe. Thanks to the Soviet support, oil and oil product consumption in Cuba increase from about 2.3 million MT in 1959 to 11.7 million MT in 1988. The growth rate of oil and oil product consumption had been greater than national income growth over the period. (Perez-Lopez, 1991)

But since the Special Period, that kind of energy consumption could not be sustained. In 1990, the Cuban government issued the imposition of mandatory energy conservation measures in response to the cessation of 2 million ton oil and oil product supply from the Soviet Union. The measures included reduction of the state fuel oil supply, cut-back of plants' operation hours, household electricity consumption reduction, replacement of agricultural tractors with animals, etc. (Perez-Lopez, 1991) Another important effort to solve the energy crisis in Cuba is the Programa de Ahorros de Energia Cubana (PAEC) implemented in 1997. The policy makers reasoned that energy savings from efficient use are equivalent with energy generation and called it "nega-watts". (Benjamin-Alvarado, 2006)

Specifically, a set of policy was made in transportation sector by the Central Communist Party Congress in 1997. They induced measures to upgrade international ports, improve public transport (buses and railways), and promote the use of bicycles. (Enoch, *et al*., 2004) Quinn (2006) is reporting the changes in transportation. Due to fuel shortage, ride sharing became common in Cuba. Hand-made wheelbarrows, buses, other motorized transport like rickshaws and animal-powered vehicles are all in service for this purpose. A tractor pulled bus nicknamed a "camel" is carrying 300 passengers in Havana. Small cars were remodeled to carry more people. An average size Chevrolet can carry eight people. Bicycles are widely used, too.

Cuba has improved energy efficiency in electricity generation, too. They have modernizing thermal power plants and adopted combined cycle power plants using associated gas. Renewed transmission lines also reduced electricity losses. (Pérez, *et al*., 2005)

3.3. Renewable Energy

Cuba has been desperate to utilize its renewable energy source. In 1993, the National Parliament approved the National Energy Sources Development Programme to promote use of renewable resources such as biomass, wind, solar, and hydro for energy production. In 2002, Commission for the Development of Renewable Energy, an inter-ministerial organization, was created. (GEF, 2004b)

First, Cuba has been trying to produce more electricity from biomass. Cuba's ministry of sugar planned to install 100 MW cogeneration equipments in sugar mills by 2000. By 2011, total of 400 MW capacities from processing sugar cane residue are expected to be built. If the plan were to be fulfilled, 10% of national electricity supply would have been additionally produced in sugar industries. Cuba has been also searching for ways to use coffee bran and rice hulls as fuels. (Lippman, *et al*., 1997) The report that the crude of price of US$50 per barrel or more will ensure the sugar cane cogeneration's feasibility in Cuba can also give confidence to its policy makers (Alonso Pippo, *et al*., 2007).

That is not all. According to a recent report, biogas is successfully mitigating the nation's energy famine. Using animal manure or agricultural industry wastes, the energy department of Villa Clara province is boasting that they have produced over 600,000 cubic meters of biogas during the last ten years. It is estimated to be equivalent to 400 tons of petroleum. (Fulgueiras, 2003) As of 2003, there are 100 biogas plants in operation. (GEF, 2004b)

Table 4. Students in PV Powered Cuban Schools (Stone, 2001)

Student Population	Number of Schools
1	21
2 ~ 5	357
6 ~ 10	483
11 ~ 20	518
21 ~ 40	385
41+	180
Total	1,944

Second, Cuba has been working on solar and wind energy. Cuba's geographical location is a great advantage for utilizing solar radiation that is more than 5 kWh/m^2/day throughout the year and similar to that of southern Arizona. The Cuban government, non-governmental organizations, and foreign aid collaborated to supply electricity to community clinics, rural homes, and small communities (Lippman, *et al*., 1997). Cuba electrified all schools that didn't have electricity by photovoltaic panels (Table 4; as of 2005, the number of PV powered school had increased to 2,364 (Quinn, 2006)). As of 2003, about 7,000 photovoltaic systems were installed and generating 1.1 MW of electricity. Although large-scale wind potential is not so

strong in Cuba, small-scale wind turbines for demonstration or for grid-connection are consistently constructed. Additionally, the support from the Global Environment Facility is shedding a light on Cuba's renewable energy. GEF is operating in Cuba to build infrastructure for renewable energy in Isla de la Juventud, a small island south of the main island. The project began in 2005 and will be finished 2010. The total cost of project will be over 16 million dollars, including GEF's $5.3 million capital support and private parts' $8.7 million investment. (GEF, 2004b)

3.4. Agriculture Using Less Energy

Responding to severe energy deficit, Cuba has implemented an alternative agriculture.

Oppenheim (2001) has well summarized their efforts. First, to reduce insecticide consumption that required large amount of energy from agro-chemistry, they have introduced biological control agents to protect crops against pests. Species from bacteria, fungi, parasites, ants, and nematodes were deployed. Second, Cuban scientists have seen some success to find antagonist microorganism to biologically control plant diseases and Cuban farmers could avoid use of fungicides and other chemicals. Third, reduction of pesticides was another imperative to use less energy. Crop rotation was effective. Competitive crops like corn were able to suppress small weeds for one year. The next year, beans could grow without significant threat of weeds. Fourth, Cuban farmers used organic soil management to reduce fossil-fuel consuming fertilizer application. Introduction of microbes such as nitrogen-fixing bacteria, bacteria that make more phosphorous available and root-symbiotic fungi micorrhizae was successful. Green manure using a fast-growing legume, inter-cropping, large-scale production of earthworm humus, and sugarcane residue recycling also enriched Cuban soil without chemicals.

Urban agriculture is one of Cuban people's efforts to solve energy shortage. Because vehicle fuels are not sufficient, it is not easy for urban residents to buy cheap vegetables from far-away farms. So they started to grow vegetables on their balconies, patios, and rooftops. To help the urban population, the Ministry of Agriculture (MINAGRI) has made a department exclusively for the capital city Havana in 1994. Since then, Cuban people made use of every small patch of land in urban area. (Bas, 2006) Thanks to this 'urban agriculture', half of the Havana's vegetable consumption and 60% of the Cuba's overall vegetable consumption are produced in urban gardens (Pfeiffer, 2006).

The result is remarkable. While Cuba's population has increased from 10.7 million in 1990-1992 to 11.3 million in 2001-2003, the number of undernourished people fell from 0.7 million down to 0.2 million. In contrast, its energy-rich neighbor Venezuela's undernourished population increased from 2.3 million to 4.5 million during the same period. (FAO, 2006)

4. Cuba's Sustainable Energy Future - Environmental Concerns

Cuba's efforts to reduce energy dependency have been successful in many ways. Air pollution was improved. Emissions of CO_2, N_2O, NO_X, CO, and VOC (volatile organic compounds) have been decreasing or flattened, although the concentrations of SO_2, CO, VOC from the electricity generation sector have began to exceed the level before the Special Period. (Pérez, *et al*., 2003)

But in the small island, the resource independence resulted in over-exploitation of domestic resources, too. Table 5 is summarizing factors that are threatening the environmental integrity of Cuba.

Urban degradation decreased over the Special Period, resulting from less effluent from cities. Industrial wastewater and sludge also decreased. Municipal wastewater's relatively high risk is due to insufficient treatment facilities, even though the amount of effluent does not seem to have increased.

Table 5. Risk ranking of problem areas before and after the Special Period (Maal-Bared, 2006)

Category	**Before Special Period**	**After Special Period**
High risk	1.5. Terrestrial degradation	1. Terrestrial degradation
	1.5. Industrial waste water and sludge	2. Freshwater and wetland degradation
	3. Freshwater and wetland degradation	4. Surface water stressors
	5.5. Surface water stressors	4. Municipal waste water and sludge
	5.5. Pesticides 5.5. Industrial solid waste sites	4. Marine coastal degradation
	5.5. Marine coastal degradation	
Moderate risk	9. Municipal waste water and sludge	7.5. Municipal solid waste sites
	9. Municipal solid waste sites	7.5. Industrial solid waste sites
	9. Airborne lead	7.5. Pesticides
	12. Hazardous air pollutants	7.5. Airborne lead
	12. Urban degradation	10. Industrial waste water and sludge
	12. Medical solid waste sites	11. Urban degradation
		12. Hazardous air pollutants
Low risk	14. Radiation	13. Medical solid waste sites
	15. Sulfur oxides and nitrogen oxides	14.5. Radiation
	16. Particulate matter	14.5. Sulfur oxides and nitrogen oxides
	17. Groundwater stressors	16. Particulate matter
		17. Groundwater stressors

But terrestrial, freshwater, and wetland degradation didn't abate. Terrestrial degradation is mainly due to deforestation for sugar cane, tobacco, rice, citrus fruit plantations. Although Cuban government is trying to reforest the land since 1989, too much forest had already disappeared and there're still illegal cuttings reported. Irrigation is worsening terrestrial degradation, too. 70% of cultivated area is now irrigated and salinization of soil that is observed in some regions can be a serious problem to Cuban agriculture in the near future. Wetland is degraded by massive construction for tourism. Hotels and accommodation facilities near beach

have destroyed precious mangrove forests. Fishing for tourist restaurants is also depleting Cuba's marine resources. (Maal-Bared, 2006)

In response to these problems, the Cuban government adopted several policies. They adopted the National Environmental Strategy (NES) in 1997 to address conflicting problems between the environment and development. The National Biodiversity Strategy and Action Plan is to protect ecologically susceptible areas. The National Environmental Fund, environmental education, information dissemination programs are also in operation. (CDCC, 2003)

5. Conclusion – Lessons from Cuba

With the U.S. embargo that has been imposed on Cuba for almost half a century, Cuba has well survived. Although the collapse of U.S.S.R. brought a critical material shortage, Cuba has not lost its economic and political integrity. Especially in its energy sector, Cuba's achievement is evident. While trying to develop domestic oil and natural gas reserve, the island country also have taken measures to save energy. Renewable energy sources contributed to Cuba's efforts to make them more energy-independent. Organic agriculture and urban agriculture using much less energy than before were marvelously developed. Although there're some environmental problems, Cuba's energy future seems to be sustainable. The promising deep ocean oil and natural gas reserves are additional gift for this country.

Cuba's experience can teach lessons for many countries. First, countries in energy famine like North Korea must learn from Cuba its energy savings and organic agriculture. Second, every country should learn how Cuba has changed their way of life in the Special Period. Any country can suffer from energy depletion whether it's due to political instability in energy exporting countries or it's due to irreversible global depletion of non-renewable energy resource.

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