Distributed generation in Cuba

part of a transition towards a new energy paradigm

Cuba depends on fossil fuels to generate electricity and the country consumes 7.6 million tons of oil a year. Before 1959, the Cuban Electric Power Industry was controlled by foreign capital. The process of nationalization carried out by the Cuban Government in the early 1960s resulted in an oil blockade, thus forcing the country to import oil from the former Soviet Union.

When the Soviet Union collapsed in 1990, the impact on the Cuban economy was devastating, with Cuba’s oil consumption falling by 20% in only two years. The effect of this was felt immediately across all sectors; transport, industry and agriculture virtually collapsed. Blackouts lasting up to 16 hours became a common issue.

Renewable energy technologies began to be deployed in Cuba at the end of the 19th century. There were applications of hydroelectricity, solar water heating, solar drying of coffee, cocoa, and herbal medicines, as well as water pumping with wind energy. The installation, in 1930, of the Ocean Thermal Energy Conversion (OTEC) plant in the Bay of Matanzas (22 kW), was an historical event. In the second half of the 20th century, the country began the qualification of specialized human capital, and scientific research into solar cells, solar dryers, solar water heaters and wind energy was conducted. Today the country is implementing renewable energy technology application projects at national scale.

The Cuban Electricity Saving Programme and the Energy Saving Programme of the Ministry of Education (PAEME) were launched in 1997. Both programmes have had good results in demand side management, energy efficiency and

Figure 1. Electricity consumption per sector in Cuba

Diesel generator cluster in Pinar del Rio. Credit: Pablo Massip Ginestá

More than 40% of the electricity generation capacity in Cuba is small-scale distributed plant. This is among the highest proportions in the world, although around half are diesel generators. The country is making progress towards its goal of a ‘new energy paradigm’ writes Mario Alberto Arrastía Avila.
energy education. Nevertheless, during the last five years, frequent interruptions in old oil-fired power stations, which only guaranteed an average availability of 60%, worsened with the impact of hurricanes on the high-voltage transmission lines. All the above mentioned affected the Cuban economy and resulted in an energy crisis. The solution was an initiative called the Energy Revolution of Cuba.

THE CUBAN ENERGY REVOLUTION

The Energy Revolution of Cuba is a radical change in the way the country transforms and uses energy carriers, technologies and sources. In practical terms, the Energy Revolution of Cuba has been the way out of the energy crisis suffered by Cuba during the period 2003–2005, but the strategy will allow the transition of the country towards a New Energy Paradigm.

The main goals of the Cuban Energy Revolution are to guarantee sustainable development and the economic and energy invulnerability of the country. The government has sold new highly efficient appliances like domestic refrigerators, electric pressure cookers and others, to more than three million Cuban families that benefited from bank loans. As a result of the application of the new concepts, Cuba has been the first country in the world to phase out inefficient lighting; approximately ten million incandescent bulbs were substituted by fluorescent lamps. The energy efficiency campaign also comprises of fuel for cooking, and in this regard, kerosene and LPG are being displaced by electricity. A stricter control on fuel and electricity consumption is one of the measures taken within the new Energy Strategy.

Combined cycle gas-fired power stations and renewable energy sources are also playing a key role within the framework of the Cuban transition to a New Energy Paradigm. The use of wind energy for water pumping and electricity generation, and solar thermal energy for water heating in houses, social institutions and certain industries, are experiencing an expansion. Rehabilitation of distribution power lines in order to decrease energy losses, the increase in the national oil and natural gas output, and the promotion of international co-operation, have all been identified as priorities. The originality of the Cuban Energy Revolution lies on the integration of technical, educational, social and economic measures.

DISTRIBUTED GENERATION

The energy crisis faced by Cuba in the period 2003–2005 worsened in the summer of 2004, and reduced the scope for establishing and implementing an energy strategy. Distributed generation (DG) overcame the situation in a very short time. Most of the new DG installations in the country are emergency generators and motors that burn fossil fuels, both diesel and fuel oil. These technologies have had a positive impact on the environment because they have lower specific consumption rates (234 g/kWh) compared to large oil-fired power plants (284 g/kWh on average). Nevertheless, local pollution (noise, NOx, SO2 and particle emissions) is a problem that needs to be addressed.

The generalization of DG meant a true Energy Revolution in itself, because it was necessary to change the traditional way in which electricity was generated in the country. Though large thermal power plants had played an important role in the development of the country, they had become obsolete. This situation worsened even more as a result of hurricanes that caused huge damage to the transmission and distribution power lines. Damage to the lines interconnecting the entire country from east to west, made the country even more

### Table 1. Comparative data on energy in Cuba

<table>
<thead>
<tr>
<th>Energy and social data</th>
<th>1958</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (million of inhabitants)</td>
<td>5.6</td>
<td>11.4</td>
</tr>
<tr>
<td>Power installed (MW)</td>
<td>397</td>
<td>5,861</td>
</tr>
<tr>
<td>Access to electricity (%)</td>
<td>56</td>
<td>96</td>
</tr>
<tr>
<td>Gross electricity generation (GWh)</td>
<td>2,550</td>
<td>16,694</td>
</tr>
<tr>
<td>Specific fuel consumption (g/kWh)</td>
<td>399</td>
<td>274</td>
</tr>
<tr>
<td>Total of consumers</td>
<td>772,000</td>
<td>3,200,000</td>
</tr>
<tr>
<td>Electricity consumption (kWh)</td>
<td>377</td>
<td>1486</td>
</tr>
</tbody>
</table>

### Figure 2. Power installed capacity in Cuba by technology in MW (2007)
Distributed generation in Cuba

vulnerable. Also, due to the dispersion of the power plants, there were a high percentage of technical losses in the transmission of electricity.

Cuba has a generating capacity of 2497 MW based on distributed generation – 1280 MW corresponds to diesel generators and the rest are fuel oil motors (540 MW), CHP (529 MW) and renewable technologies (69 MW). The country also has a reserve of more than 6000 small diesel generators installed in key centres of the economy and services to the population such as bakeries, shopping centres, hospitals, clinics, food production sites, and schools, among others. The combined power of all these generators reaches the figure of 690 MW and the purpose is to interconnect them to the National Electrical Grid.

The DG model of electricity generation has shown its benefits in terms of resistance to natural disasters. This has been illustrated after the impact of two hurricanes on the Cuban territory within two weeks of August/September, when more than 130 transmission line towers were destroyed in the western province of Pinar del Río. Distribution lines in the eastern part of the country and the centralized power station located in Nuevitas, north of Camaguey province, also suffered tremendous damage as well. Although the magnitude of the disaster created by the hurricanes was compared to a nuclear bomb, decentralized energy systems remained operational and guaranteed critical services and water supply. After the hurricanes, diesel gensets were situated in specific places creating micro-electrical systems, or islands, in order to guarantee the services to the population.

DISTRIBUTED RENEWABLES

Solar energy is available in Cuba throughout the year with an average value of 5 kWh/m² per day. Each day, every square metre of Cuban territory receives an amount of solar energy that is equivalent to the energy content of half a kilogram of petroleum, considering the heating capacity of oil equal to 9600 kJ/kg.

Hydroelectricity and wind-powered water pumping were the two most utilized renewable energy technologies in Cuba in the first half of the 20th century. The two oldest hydro power plants built in Cuba date back to 1912 (Pilotos, Pinar del Río province, 155 kW) and 1917 (Guaso, Guantánamo province, 1.75 MW). Both power plants are still operating. The hydropower potential in Cuba is relatively low, and whether or
The assessment of wind resources for electricity generation purposes has been accelerated since the beginning of the Energy Revolution. Today, the country has three key decision-making tools for the installation of wind farms: the map of ecological evidences of the wind, the map of risk of hurricanes, flooding and electric storms, and the national wind map.

There is a comprehensive program for the application of biogas, forest biomass, hydroenergy, solar photovoltaic, solar thermal and wind in the Isla de la Juventud Special Municipality. It is expected that the territory will satisfy 40% of its electricity demand from renewable energy sources by 2013.

The Energy Revolution in Cuba has also meant an accelerated take off in the application of renewable energy technologies. The set up the National Group for Renewable Energy Sources, Energy Efficiency and Cogeneration, the creation of a Vice Ministry for Renewable Energies attached to the Ministry of Basic Industry; the deployment of national programs for the development of electricity generation based on wind energy, solar water heating for domestic, social and industrial purposes; the development of capacities in hydro and solid waste energy; and research on geothermal, ocean energy and other technologies, all demonstrate the advances of the country in favour of the ever increasing inclusion of renewable energy technologies within the distributed generation model.

So far the country has installed 7098 photovoltaic systems (2.57 MW), with the support of foreign NGOs and from governmental programs. The latter made possible the installation of these systems on 2,364 rural schools – making lights, computers, television and videos accessible to all primary school children.

Regarding bioenergy, there is experience in the country in the use of bagasse (sugar cane residues) to produce thermal energy for the sugar production process and to generate electricity to meet the demand of sugar cane mills and send the surplus energy to the national grid. The sugar industry continues to be a strategic component of the development of domestic energy sources. After the economic crisis of the 1990s, the share of biomass in the country’s energy mix has declined.

According to Cuba: A country profile on Sustainable Development, a publication sponsored by the International Atomic Energy Agency, CUBAENERGÍA and the United Nations department of economic and social affairs, cogeneration in the sugar industry accounted for 18% of all electricity generated in the country in 1970 – by 2003 this figure had decreased to 5%. Efforts are now made to increase energy efficiency in the sugarcane industry and cogeneration is expected to increase with the installation of higher efficiency boilers and new turbo generators in operating sugar mills. The country accounts with a total CHP potential capacity of 1355 MW.

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\text{Table. CHP potential in Cuba} \\
\begin{array}{|l|c|}
\hline
\text{Sector of the economy} & \text{CHP potential (MW)} \\
\hline
\text{Sugar cane industry} & 1,250 \\
\text{Tourism} & 50 \\
\text{Health care centres} & 30 \\
\text{Metallurgy} & 25 \\
\hline
\text{TOTAL} & 1,355 \\
\hline
\end{array}
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With the Energy Revolution, two municipalities of the eastern region of the country have sped up their activities in order to achieve energy self-sufficiency from renewable energy technologies. Guamá will achieve it from the interconnection of a network of hydroelectric power plants, and Bartolomé Masó will achieve it by combining hydroenergy, photovoltaic and cogeneration in the local sugar cane industry.

**ENERGY EFFICIENCY AND EDUCATION**

Understanding that looking for more ways of generating electricity efficiently is just as important as decreasing electricity demand, Cuba began a programme to switch to efficient appliances in households. The most popular of the actions carried out as part of the Cuban Energy Revolution is the change of incandescent bulbs for energy saving lamps. This was followed by the substitution of inefficient appliances and the introduction of new ones such as electric pressure cookers and electric rice cookers. Social workers, University Brigades of Social Work and community-based organizations all distributed energy-saving bulbs and traditional fluorescent lamps free of charge. In less than a year, the country phased out inefficient lighting – the first country in the world to do so.
Almost three and a half million rice cookers and over three million pressure cookers were sold to families in the push to have people switch from kerosene to cooking with electricity. And one of the best ways to encourage conservation was the new residential electrical tariff structure. Before 2006, Cuba’s highly subsidized electricity was sold very cheaply, which did not encourage saving. The new tariff structure allows people consuming less than 100 kWh per month to continue paying the previous low rate. But for every increase of 50 kWh per month the electricity tariff skyrockets. Consumers using over 300 kWh per month must pay 1.30 Cuban pesos/kWh.

Energy education began in the 1970s in Cuba when children from primary and secondary schools were organized at neighborhood level in what were called ‘Click Patrols’, in order to promote energy saving at home. Since the introduction of PAEME, the education of all students in energy issues has been a priority for the government, but the Energy Revolution has boosted energy education activities nationwide.

The initiative Technology for the Total Efficient Energy Management promotes the education of the labour force and managers in energy issues. When social workers are appointed to work in large energy-consuming centres, they carry out energy awareness activities that contribute to better understanding, the necessity, and the way to decrease energy consumption.

In the long term, energy education is the most cost-effective method for saving energy and promoting both energy efficiency and renewable energy technologies. Therefore, the Cuban educational strategy goes far beyond increasing the domestic electric tariffs. A national educational programme on energy is taught in all the schools of the country, and the mass media promote energy saving and demonstrate the importance of taking advantage of renewable sources of energy and applying energy efficiency measures. There is a weekly programme on energy issues on the national television address to increase the energy culture to the population and scattered across the country are billboards promoting energy conservation. But in spite of the many educational and informative efforts, there is still a lot to be done, mainly in the industrial and commercial sectors.

A SUSTAINABLE ENERGY PARADIGM
Between 2005 and 2007 Cuba reduced its carbon dioxide emissions by approximately 5 million tons, which represents 18% of the total emissions of the country in 2002, according to the last report rendered by Cuba to the IPCC. The Energy Revolution has also played a key role in the country’s accomplishment of the Protocol of Montreal, as more than three million domestic refrigerators and air conditioners have been changed for efficient ones that do not use CFCs – leading to the phasing out of CFCs in the domestic sector in a short period of time.

The shift towards a more sustainable energy paradigm that is taking place in Cuba is not only characterized by energy saving measures and the implementation of efficient and renewable energy technologies, but also by paying special attention to international co-operation and encouraging the participation of youth in the different tasks to be carried out. That is why Cuba is working together with Venezuela and other Latin American nations in the implementation of strategies for the reduction of their energy demands and the use of renewable energy technologies. Cuban social workers have changed about 100 million incandescent bulbs in a dozen countries of the region. The sustainability of the Cuban Energy Revolution is guaranteed by its own educational actions.

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