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ENERGY REVOLUTION IN CUBA: PIONEERING FOR THE FUTURE?

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EXECUTIVE SUMMARY

The aim of this report is to make Cuban energy reforms more widely known. Cuba has succeeded in achieving high human development index while keeping its ecological footprint small. This is largely because of the low energy consumption in the country. At the same time the electrification rate is one of the highest in the Caribbean region. Even at the time of energy crisis the electrification continued in the remote rural areas, mostly based on renewable energy sources and having priorities set in electrifying schools, health centres and communal centres.

The Cuban Energy Revolution, which started in 2006, was the policy response to the local energy crisis; oil imports caused serious balance of payment problems, the old centralised electricity production system was inefficient and hurricanes caused wide damage to the transmission and distribution system resulting large black outs. The Energy Revolution has been quite successful in changing the energy use patterns in Cuban households. The appliance replacement program has resulted in significant reduction of kerosene, LPG and gasoline use and also in significant annual electricity savings. New progressive electricity tariff has also encouraged electricity saving in households. Cuba also experienced almost a complete shift from centralised to a distributed energy system. The decentralisation of electricity production has increased the reliability of supply and improved the efficiency when new smaller scale power plants have replaced older technology. In terms of distributed energy generation Cuba holds currently the second place in the world right after Denmark. This may better enable the future development of renewable energy.

The energy revolution has, so far, not had much impact on energy use in industry and transport which are the areas where the future policies should be directed. Also the country's energy mix still remains to be dominated by fossils. Yet, Cuba has high potential for harnessing renewable energy sources such as solar, bagasse and other biomass sources, as well as wind. It also has highly qualified scientists and experts on renewables and energy conservation, in addition to high-level government support for sustainable energy production and use. The major barrier is formed by lack of available materials and limited access to finance. For donors such as the European Commission there would be plenty of opportunities in Cuba for cooperation in supporting and fostering the agenda of sustainable energy for all.

Cuban experiences could be beneficial for South-South and North-South-South cooperation in areas of low-cost appropriate renewable energy solutions, deployment of renewable energy in electrifying remote areas, electrification programs with social goals, and when developing sustainable energy policies and energy conservation measures that also address social fairness considerations. For example the Cuban social credit system developed for the replacement of inefficient appliances and the new progressive electricity tariff deserve more international attention.

1. INTRODUCTION

Cuba has been seen as one interesting country when discussing the possibilities to shift the development paradigm to sustainable economy and society. Cuba could be seen as a pioneer especially in having high human development index while keeping its ecological footprint small. It has struggled to be more energy independent and more efficient in its energy use. Andrew Simms (2009) from New Economic Foundation has described the new interest to Cuba: "Like a nervous scout sent ahead of the main party to see what risks lurk in the valley beyond, Cuba has been hit by a triple crunch - three separate shocks that are creeping up on the rest of the world." These shocks are: decline of oil, extreme weather conditions because of climate change and an economic crisis. In the case of Cuba the decline of oil was related to the loss of cheap oil imports from Soviet Union in 1990 which required major changes in the energy systems and was a starting point for new energy policies. The collapse of Soviet Union and the US economic embargo have caused severe challenges for the Cuban economy – resulting in the economy crisis of the Special period. In addition, extreme weather conditions with high frequency of disastrous hurricanes have caused devastating problems, including to the electricity transmission and distribution system. And yet, Cuba has been recently recognized as a model of sustainable development (see e.g. Cabello et al. 2012, Perez et al. 2005, Bell 2011 and Suarez et al. 2012 on discussion of environmental issues in Cuba). According to the 2006 Living Planet report Cuba is one of the few countries in the world that has Human Development Index (HDI) more than 0,8 and at the same time ecological footprint lower than 1.8 global hectares per head. This is largely because of the low energy consumption in the country. This all in combination to the recent energy reforms makes Cuba an interesting case.

Cuba has aimed for a drastic change in its energy policy – from fossil fuels to increasing energy efficiency and the use of renewable energy. Cuba's programme of "La Revolución Energética" deserves a closer look in relation to the sustainable energy development in the Global South and world-wide[1]. The energy reform has launched various energy saving measures. In addition, Cuba has been striving for decentralized power production and is highly motivated to develop renewable energy sources: wind farms, micro-hydro systems, independent solar electric systems, biogas plants and biomass facilities. Moreover, Cuba has already started exporting its Energy Revolution to other Southern countries in the framework of the Bolivarian Alternative for the Americas (ALBA) and developed interesting models for South-South renewable energy cooperation.

Another key feature of Cuba's energy policy is that the strong will to save energy and shift to renewable energy sources is facing several obstacles, not least in terms of lack of materials and investments. In con-

[1] Another area of reforms is the agriculture. Cuba has been seen as the country showing the way how the agriculture can be made less dependent on fossil fuels. It has also served as a model for urban gardening experiments. (Wright 2009)

trast to several other developing countries, in Cuba the agenda of renewable and sustainable energy has a relatively strong and wide ownership in the country, especially among the government. There is also a relatively high level of human resources and capacities in the energy domain. But there are very few donors and investors interested in working in the country. Partly this relates to major reform needs in the governance of energy issues and related investments.

This report discusses the energy use in Cuba, the Cuban energy revolution and the changes that have taken place. The report is a based on literature review as well as on a two weeks fact finding mission in November 2011 with several meetings, presentations, interviews and visits with Cuban experts. Workshops, interviews and meetings were organized with experts from Cubaenergía in Havanna and with experts from Universidad de Oriente and Centro de Investigaciones de Energía Solar (CIES) in Santiago de Cuba (See Annex 1). Visits included also Swine Research Institute with its biogas pilot site near Havana.

The aim of this report is to make Cuban energy reforms more widely known and to feed Cuban experiences constructively into the debates on models of sustainable energy production. The report may also inform EU's energy related aid and initiatives in supporting sustainable energy transitions. What could be the lessons learnt from the Cuban experiences with various energy saving measures? What kind of potential there is related to the decentralized power production systems that rely on renewable energy sources (wind farms, micro-hydro systems, independent solar electric systems, biogas plants and biomass facilities)? And what are the main challenges?

The report is part of a project funded by EuropeAid which has been implemented in nine EU countries by a consortium of seven European organizations, mostly civil society organisations but also research institutes, cooperating closely with Southern partners. The objective of the project is to improve EU's external policies regarding the urgent need for sustainable energy for all, especially for the most vulnerable sectors of societies in the South, by researching and making accessible information about the challenges to the supply of sustainable energy to the poor and by stimulating public debate and demand for sustainable policy changes.

The report is structured in following manner. First an overlook is given on Cuban energy development, secondly the energy revolution that started in 2006 is discussed in more details, thirdly the state and potential of different renewable energy options are explored, and fourthly these are discussed in relation to the current governance challenges. Finally conclusions and recommendations for donors such as the EU are provided.

2. CURRENT SITUATION AND A BRIEF ENERGY HISTORY OF CUBA

CUBA'S ENERGY PROFILE

Electrification rate: 97% (in 2009)

- 90 % are connected to the grid. 6-7 % in off-grid areas get electricity from gensets, small hydropower stations or solar PVs

Installed electricity production capacity: approx. 6000 MW

Energy demand in Havana: approx. 500 MW

Renewable energy in electricity production: 4% (in 2011)

Renewable energy in primary production: 20% (2009)

42% of production capacity in distributed systems

Key characteristics of the Cuban power sector include on the one hand relatively high electrification rate (one of the highest in the region) but low energy consumption per capita (one of the lowest in the region), and on the other hand high dependence on fossil energy and imported oil but a long history of interest in harvesting domestic renewable energy sources. The dependence on subsidized, imported oil, first from Soviet Union and later from Venezuela, has made Cuba vulnerable for outside changes in political landscape (cf. collapse of the Soviet Union and now dependence on current Venezuelan power regime) as well as increased the will to look for domestic energy sources including solutions in energy saving measures and in renewable energy.

Prior to the Cuban revolution in 1959, about half of the households had access to electricity. By 1989, the electrification rate had risen to 95 per cent and in 2009 the rate was 97 per cent. Several remote rural areas have been provided small-scale off-grid systems powered by gensets, small hydropower or solar PVs. (Suarez et al. 2012.)

Cuba has been and still is heavily reliant on fossil energy in its power generation. In 2009 95% of the power production was based on fossils (see *Table 1*). Most of the electricity in the country is produced by thermoelectric plants that are powered by the hydrocarbons, mostly oil, but also natural gas. Around half of the oil is from domestic sources and the rest is imported from Venezuela (see

Figure). In 2009 3.6 percent and in 2012 4 percent of the electric power generated came from renewable sources (Suarez et al. 2012). In primary energy production, however, the share of renewable energy is much higher, accounting up-to 20%, due to the use of bagasse-fired energy in the sugar industry (See *Figure*). In electricity production the role of renewables is greatest in off-grid systems used in the remote areas of the country. But this may change in future as several efforts have been underway to increase the role of renewables in the electricity production.

Another key characteristic of the Cuban energy sector is the relatively high share of distributed energy production (around 40%), which partly has been developed as a response to high exposure to damages caused by extreme weather conditions, including hurricanes. In terms of distributed energy generation Cuba holds the second place in the world right after Denmark. The generalization of distributed generation has been part of the Energy Revolution Program launched in 2006. Another concrete achievement of the program has been the energy saving measures targeting mainly domestic energy use. This is relevant for the

overall power consumption: in 2009 household power consumption was 36% and the industrial consumption 25%.

Picture 1. Old thermoelectric power plant in Santiago de Cuba.

The energy intensity in Cuba has been decreasing since 1997. Related to this one of the interviewed experts stated that "if we would be an Annex 2 country, we would be a very fine exemplary country in climate change mitigation because our energy intensity has been clearly decreasing in the recent past". The explanation, however, is not primarily the concern on climate change but can be explained by the economic crisis and growing importance of the service sector in the Cuban economy. Yet, the importance of the measures of the Cuban energy revolution and the increased attention paid on sustainability aspects of development should not be dismissed either.

Table 1. Structure of the gross power generation in Cuba 2009. Sources: Suarez et al. 2007, Statistical Yearbook of Cuba 2009.

Type of generator	Units	Power (MW)	Production (GWh)	Production (%)
Oil-Fired Power Station	9	2273	10772	58
Gas-Fired Power Station	2	495	2381	13
Fuel Oil Generators	416	904	3122	17
Diesel Generators	893	1220	1130	6
Old Diesel Generators	5	99	150	0,8
Nickel Industry Generator	3	214	333	1,8
Renewable energy				
Bagasse-Fired Power Plant	54	332	517	2,8
Hydroelectric	180	58	151	0,8
Wind Parks	3	7	3	0,02
Renewable energy in total	-	398	671	3,6

Total	-	5602	18559	100

To understand the changes in Cuba's energy sector it is important to look at the wider historical context. From 1958 until the collapse of the former Soviet Union, Cuba traded sugar for oil with the Soviet Union on very reasonable terms. When the Soviet Union collapsed in 1991 Soviet subsidies and trade links were rapidly withdrawn. This caused a shock for Cuba and its GDP fell 35% between 1989 and 1993 (see *Figure*). The era of cheap electricity ended. This period (1990-1994) was called by then-President Fidel Castro as "the Special Period in Peacetime". The Special Period was an emergency economic regime marked by extreme austerity and shortages. Oil, gas and food all became scarce. Imports from Russia dropped by 50 percent, and oil consumption dropped 20 percent, from 225,000 barrels a day in 1989 to 180,000 barrels a day in 1992 (Avila& Guevara-Stone 2009) (see

Figure). Transport was hit hard, along with electric generation. Biofuels were mainly used in sugar industry and due to the reduction in sugar processing the use of bioenergy decreased.

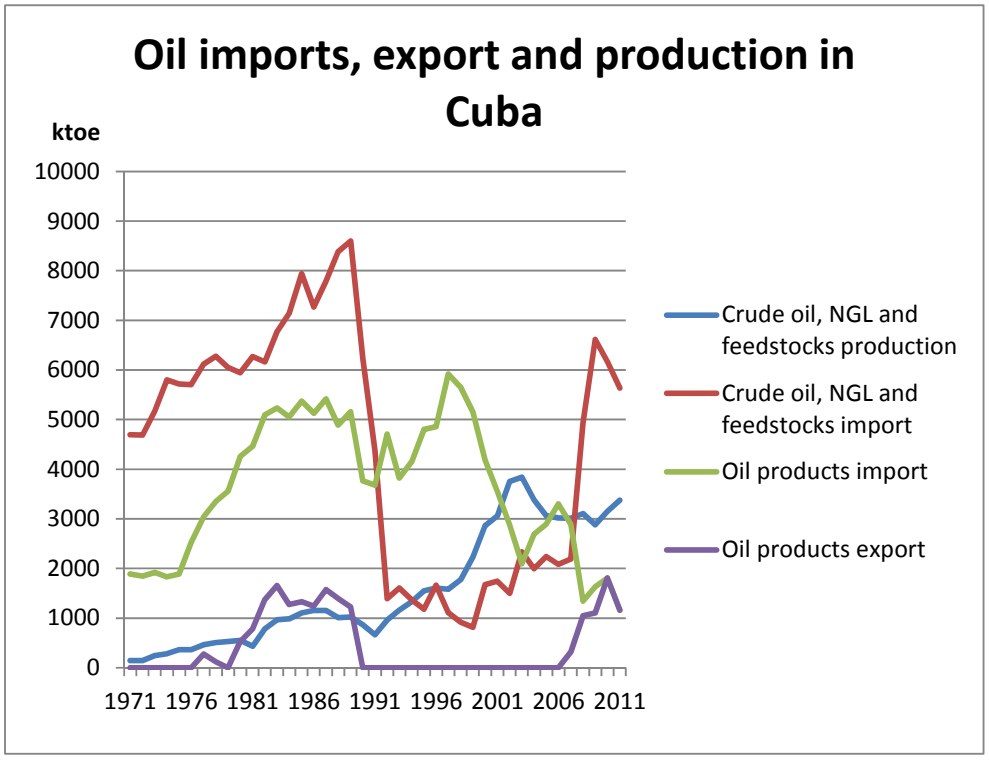

Figure 1. Oil imports, export and production in Cuba. Data source IEA 2013.

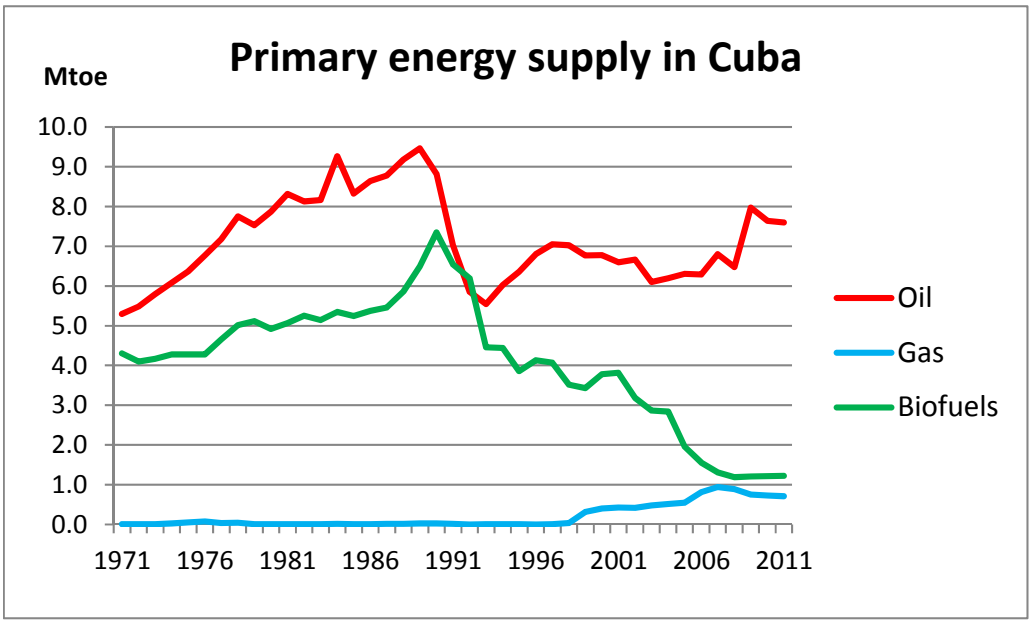

Figure 2. Primary energy sources in Cuba. Data source IEA 2013.

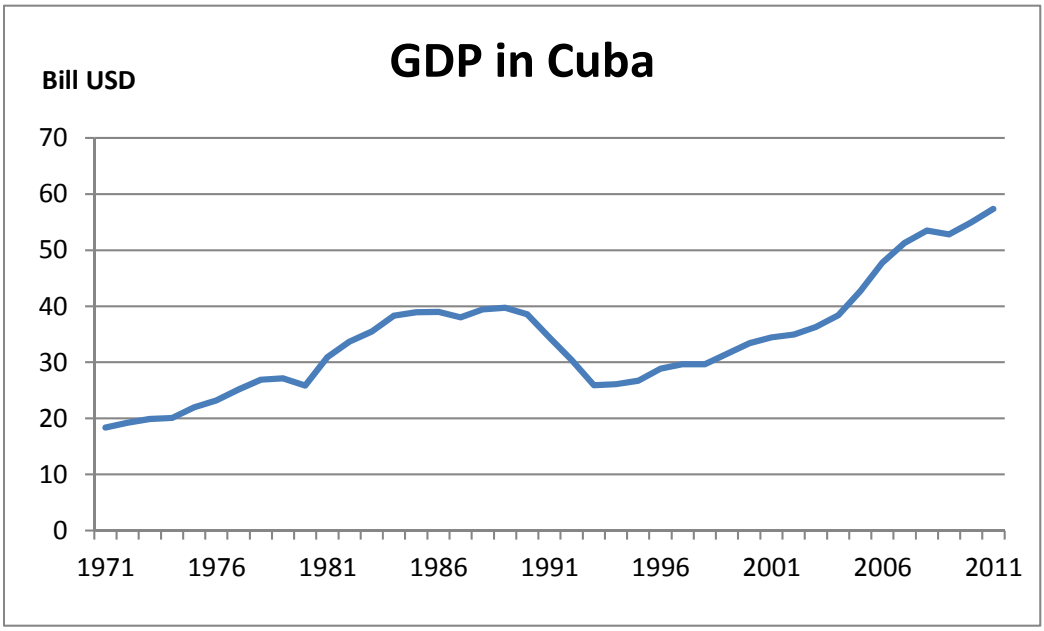

Figure 3. Development of GDP in Cuba. Data source IEA 2013.

In the special period Cubans had to learn how to produce more of their energy and food locally. The response for the Special Period in the energy sector was the National Energy Sources Development Programme (Programa de Fuentes Nacionales) approved by the Cuban National Assembly in 1993 (Marín & Curbelo (2005). Three areas of actions were prioritized: 1) Energy efficiency and renewable energy, 2) The increase in national crude oil production (that is found together with gas) for electricity generation as a substitute for imported fuel oil and 3) Sugar industry to achieve higher efficiency in the use of bagasse. These are discussed in the sections below.

Several measures and efforts were made to reach the objective of increasing domestic crude oil production. The domestic production of oil started already in the 1970's, but it grew considerably after 1990 and the 1993 National Energy Development Programme (see Figure). Currently almost half of the oil is domestically produced and the rest is imported mainly from Venezuela. The problem is that the domestic oil is principally from shallow waters just off the coast and it consists of low quality, high-sulphur heavy oil. As one interviewed expert commented: "Without the embargo this high sulphur content oil would have been used for making asphalt, not for energy production. But after the Soviet support was gone we had to turn for our national oil reserves". All thermal systems in Cuba use this domestic low quality oil. The high sulphur content level of this oil is one of the main factors leading to failures in power stations. Cuba does also have some offshore "high quality" oil and gas reserves of its own and the future potential for the off-shore production is seen quite significant, but these expectations are yet to be materialised (Piñon & Benjamin-Alvaredo 2010). Natural gas production has increased during the last years. The gas has been used mainly for commercial and residential purposes, but with increased production, gas is also used to produce electricity. In terms of imported oil Cuba began first to buy oil from the open market in the beginning of 1990's. In the more recent past, however, a significant change with the oil imports was brought by the favourable trade terms developed with Venezuela (after Hugo Chavez was elected as president in 1998). Some of the oil from Venezuela is financed by loans, part is a barter trade involving about 20,000 Cuban medical professionals who work in Venezuela, and some oil is provided as a grant (Soligo and Myers Jaffe 2010, 80)[2]. Although on the one hand the deal with Venezuela has been essential for the recovery of the Cuban economy, on the other hand it has once again made Cuba dependent on subsidized imported oil.

"Without the embargo this high sulphur content oil would have been used for making asphalt, not for energy production. But after the Soviet support was gone we had to turn for our national oil reserves".

In terms of renewable energy the Special Period and the 1993 energy programme sparked mobilisation in the Cuban scientific community to look at new alternatives. In addition, thanks for the new initiatives in renewable energy, the electrification rate increased despite the energy crisis. Rural schools, health clinics and social centres in remote off-grid areas were provided electricity via solar PV-systems or micro-hydro plants (Barclay 2003, Cherni & Hill 2009). New actors also evolved – a company Ecosol Solar and an NGO Cubasolar built a productive partnership in the 1990's with funding from overseas and since the end of the 1990's they have been active in spreading solar PV systems especially to rural schools in remote areas. Making lights, computers and educational television programs accessible to every school child in the country won Cuba the Global 500 Award from the United Nations in 2001 (Guevara-Stone 2009). By 2003 over 2364 schools, 350 doctors' offices,

Thanks for the new initiatives in renewable energy, the electrification rate increased despite the energy crisis.

[2] Venezuela has also financed the completion of the Cienfuegos refinery opened in 2007, and provided finance to the acquisition of tankers to carry Venezuelan crude and products to Cuba.

and hundreds of hospitals had been equipped with solar PV systems (Barclay 2003). After 2002 in addition to health stations and schools, also private homes have been electrified with solar PVs.

For the sugar industry the efforts were not as productive. Cuba was unable to find market for its sugar production after Soviet Union collapsed and the industry suffered seriously in the special period. In 2002 major restructuring took place with the closure of 71 sugar mills and reduced planted area for sugar cane (Grogg 2007b). Altogether sugarcane production fell from 82 million ton in 1990 to 23.8 million ton in 2004. This resulted in significant reduction of bagasse use as energy source after 1990 which can be seen in *Figure 1* that describes the industrial energy use. (Alonso-Pippo et al. 2008) The proportion of electricity produced by bagasse in total primary consumption of energy dropped from 10 to 5,6 percent between 1990 and 2002 (Grogg 2007a).

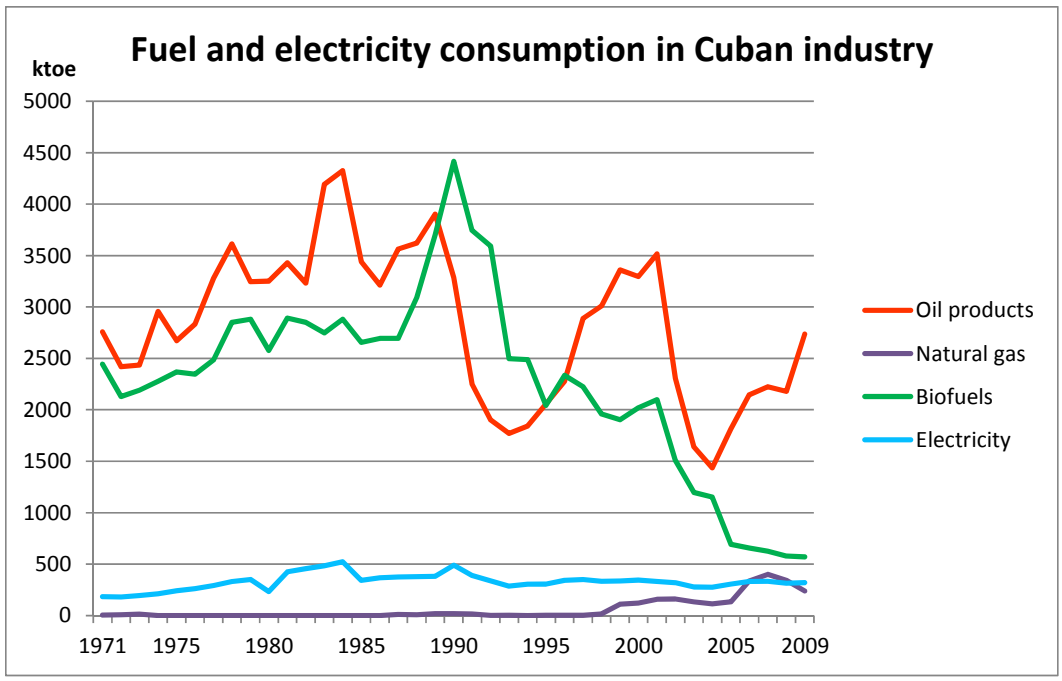

Figure 1. Industrial energy use in Cuba. (Data source: IEA 2011).

3. FROM ENERGY CRISIS TO ENERGY REVOLUTION

> *"We are not waiting for fuel to fall from the sky, because we have discovered, fortunately, something much more important: energy conservation, which is like finding a great oil deposit."*
>
> – President Fidel Castro in 2006 (quoted in Guevara-Stone 2009)

In the early-2000s Cuba's energy situation was bleak. Cuba had centralized and inefficient power plants: 11 thermoelectric plants that functioned about half of the time. Power plant failures were partly caused by the widespread use of poor quality fuel with high content of sulphur but also the grid was in bad condition. The problems culminated when two hurricanes caused considerable damage in the transmission line in 2004 leaving a million people without electricity for 10 days. The worst year was 2005 when the national electricity system functioned at only 50 % of its installed capacity with blackouts lasting seven to twelve hours on a daily basis (Benjamin-Alvarado 2010). Moreover, most Cubans had inefficient appliances, highly subsidised residential electricity rates did not encourage conservation, and 85 per cent of the population cooked with kerosene (Avila 2009).

In the face of energy crisis consisting of an antiquated and damaged system with power shortages energy sector was made a priority in Cuba (Guevara-Stone 2009, Suarez et al. 2012). In 2006 Cuba embarked on Revolución Energética, Energy Revolution – an initiative or policy that aimed to save energy and use more sustainable sources more efficiently. It had the following main aspects:

- Energy efficiency and conservation
- Increasing the availability and reliability of the national grid
- The generalization of distributed generation with smaller electric power plants
- Incorporating more renewable energy technologies into its energy portfolio
- Increasing the exploration and production of local oil and gas
- International co-operation

The first step in the energy revolution was to decrease energy demand by energy efficiency and conservation measures. This will be the focus in this section but the other dimensions of the launched energy measures are briefly discussed as well.

Energy efficiency and conservation

An elemental part of the Energy Revolution has been the replacement of household appliances with more efficient and safer equipment. These were supplied free or at low cost and also some social credit schemes were developed.

Households switched their incandescent light bulbs to more efficient compact fluorescents free of charge. This was done with the help of 13 000 social workers around the country. This made Cuba to be the first country in the world to phase out the use of incandescent light bulbs.

Cuba was the first country in the world to phase out the use of incandescent light bulbs.

As one interviewed energy expert from Cubaenergía stated: "Many countries have tried to do this, but not very successfully. For example Australia made a decision to shift to energy saving light bulbs in 2007 but they still have not accomplished their targets. Here in Cuba we did it basically in 6 months. This shift to energy saving lamps could be estimated to have saved the amount of energy produced by one large power plant." The shift to energy saving lamps has been estimated to result in annual saving of around 3-4% of the total Cuban electricity consumption (354 million kWh) (Seifried 2013).

Box 1. Energy Revolution by numbers – replacement of old technology with more energy efficient technology

Substitution of approximately 9.4 million incandescent bulbs replaced
Targeted the inefficient appliances of over 3 million households
2 million refrigerators replaced
Over 1 million fans replaced
182,000 air conditioners/ventilators replaced
260,000 water pumps replaced
Cooking with kerosene replaced with electricity: 3,5 million rice cookers and 5,5 million pressure cookers distributed
New residential electricity tariff was introduced with lowered level of government subsidies to encourage electricity saving

Source: Guevara-Stone 2009, Suarez et al. 2012

But the lamps were not the only problem. The biggest "energy monsters" were the old refrigerators from the 50's and the ventilators that have been made from old Russian washing machines (a remarkable 'grassroots' innovation in itself of course, but a very energy consuming one). Since 2006, 2 million refrigerators and one million fans have been replaced. The annual electricity savings for the replacement of old refrigerators have been estimated to amount for 1 147,5 million kWh (Seifried 2013). The scheme for the refrigerators was that government provided 50 percent and the household 50 percent of the costs. There was also a loan system created for this in which the interest rates and payback times were adjusted to the household's income level and payback ability. For example for the lowest income levels (monthly in come up to 225 Cuban pesos), the interest rate was 2% and payback time 10 years. In addition there was a cooperation programme with Canada to store the gases in the final destruction of the old refrigerators to avoid CFC emissions.

Another problem area targeted by the energy revolution was the high use of kerosene in households for cooking. Before the revolution the main source for cooking energy was charcoal. Later on Soviet Union provided a cheap supply of kerosene which replaced the charcoal use. Only food production in some service units continued with the charcoal use. With the energy revolution the kerosene and LPG use has been largely replaced by 3,2 million new electric stoves (a simple electric hotplate) and by distributing 3,5 million rice cookers and 5,5 million pressure cookers to Cuban households.

Picture 2. Electric stove.

Additionally new residential electricity tariff was introduced to encourage electricity saving. The tariff was created with social fairness considerations. People consuming less than 100kWh per month still continue to pay previous, significantly subsidised, low rate (0,38 US cents/kWh), but for every increase of 50 kWh per month the tariff progressively increases and the large consumers need to pay around four times more than before (Avila 2008, Guevara-Stone 2009).

Along with the changes in appliances, technology and the introduction of the electricity tariff, an important element of the energy revolution has been energy education. Educational efforts have included awareness raising on energy saving measures: special courses, contests and festivals for students in schools; published books; courses for journalists; several types of printed materials, TV classes, radio and TV spots as well as newspaper articles(in 2007 alone around 8000 articles and TV spots); as well as around 4 million prepaid phonecards with information on climate change and renewable energy. There has been also dissemination of instructions on the use of PV panels. (Avila 2008, Guevara-Stone 2009)

National grid and distributed electricity generation

According to Suarez et al. (2012) 90% of the national grid has been rehabilitated after the Energy Revolution started, with upgraded electrical posts, utility service entrances and electrical meters. But perhaps more importantly, the extension of distributed generation was carried out decisively. Currently, 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) (ibid.). This means that 42% of the generation capacity is in distributed systems: a very significant shift away from a centralised power system. The distributed units are generally of a size of 3 to 10 MW.

Most of the new distributed generation installations in the country were emergency generators and motors that burn fossil fuels, both diesel and fuel oil. These technologies, however, have had a positive impact on the environment because they have lower specific consumption rates compared to old large oil-fired power plants (Herrera et al. 2013). It could also be expected that this transition from centralised to distributed system may contribute in fostering the future development of renewable energy sources.

Renewable energy

The Energy Revolution in Cuba has also targeted to increase the use of renewable energy technologies. It resulted in setting 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 (Avila 2009). The emphasis on increasing the use of renewable energy sources in the overall energy mix has, however, been slow and is not yet clearly visible in the statistics. The current state and future prospects for renewable energy in Cuba are discussed in more details in the Section 4.

South-South cooperation

An additional element of the energy revolution programmes has been the international cooperation with other Latin American nations like Haiti, Bolivia and Venezuela. The cooperation has covered strategies for the reduction of energy demands and the use of renewable energy technologies. (Avila 2008.) In Venezuela Cubans have assisted in carrying out an energy conservation campaign, in Haiti Cuban social workers visited 93 000 houses and installed around two million energy saving light bulbs, and in Bolivia, Honduras and Venezuela Cuban technicians have provided and installed solar PV panels (Guevara-Stone 2009).

In Venezuela Cubans have assisted in carrying out an energy conservation campaign, in Haiti Cuban social workers visited 93 000 houses and installed around two million energy saving light bulbs, and in Bolivia, Honduras and Venezuela Cuban technicians have provided and installed solar PV panels.

Results: Successes and challenges

The substitution of inefficient electric appliances has been in many ways successful but not without new challenges and concerns. Millions of energy efficient appliances are now used by consumers. How to deal with the waste from the new incandescent bulbs has not been yet entirely solved. There have been also problems with the quality of the appliances that have been bought mostly from China as bulk purchase. Problems have been also faced with repairs and purchase of spare parts. The shift to new appliances has also meant a shift to the culture of "made to break" or to "the culture of obsolescence" as one interviewed energy expert commented (cf. also Slade 2006). Chances are high that the new models from China will last only a fraction of the time the ones they replaced lasted. One concern is that in Cuba people do not have possibilities to easily buy imported appliances from the market.

The problem with the new electric stoves was that the bulk purchased models were far from optimal energy efficiency. At the moment different experts have been looking at the problem. For example in the Universidad de Oriente there is a group of people that have developed a way how to make these stoves more efficient through installation of a metal reflector in the stove. They are now looking for funding options (including the Clean Development Mechanism, CDM) to scale up their innovation.

An expert from Cubaenergía sums up the experience thus far: "We needed to act fast, so mistakes were understandably made. All in all we have taken steps to the right direction. And we have also learnt from many mistakes, so we have knowledge on what are the things that should be done differently in the future." Other limitations include the extension of energy saving measures to the production and service sector. This would require special financing mechanisms to e.g. enable the shift to high efficiency engines etc. Government planned to establish an investment bank for energy efficiency so that hotels and industries could get affordable loans for energy efficiency measures. But this plan never materialized because the banks did not manage to get loans from abroad. There would also be a demand for incentives for energy service companies to improve energy efficiency, as there are practically none at the moment.

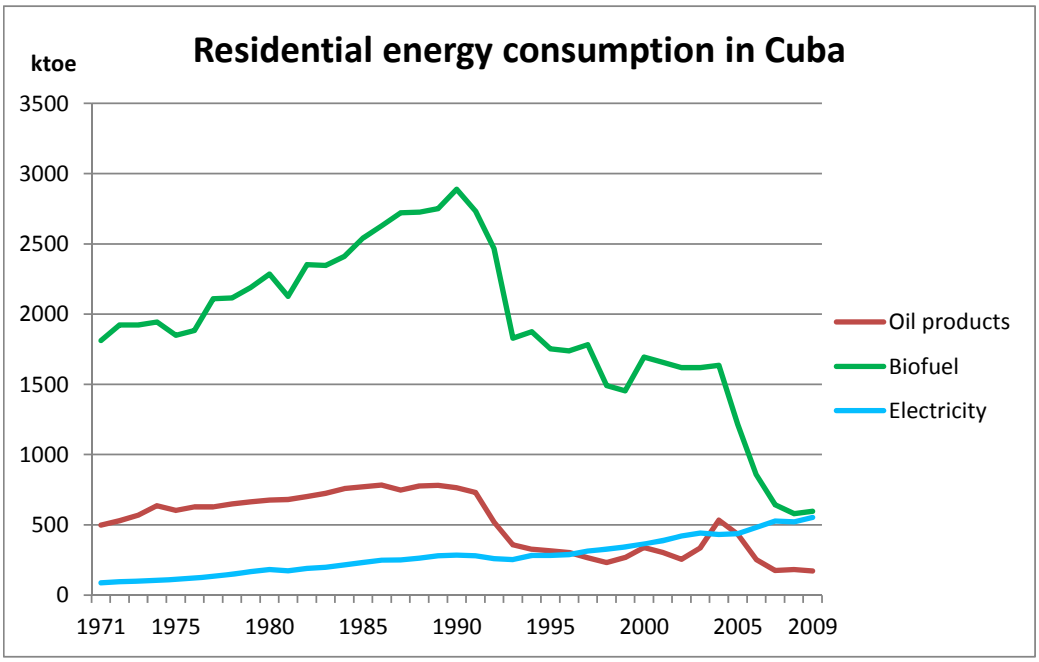

Figure 2. Residential energy consumption in Cuban households. Data source IEA 2011.

All in all many of the results are clearly positive. The program helped Cuba to stabilize its power supply and to address the problem of country-wide blackouts. The emergency preparedness was significantly strengthened, and the new hurricanes have not caused such devastation for the electricity system anymore. Here the shift to more distributed system has been essential.

The appliance replacement program has also materialised in concrete results. Two years after the Energy Revolution measures were introduced, in 2008, the kerosene consumption had decreased by 34 per cent, LPG (liquefied petroleum gas) consumption by 37 per, and Cubans consumed 80 per cent less gasoline than before the Energy Revolution. (Guevara-Stone 2009) The results of these energy saving and appliance switching methods can be seen in the residential energy consumption (see Fig. 6). After the implementation of measures the consumption of biofuels and petroleum products has decreased while the electricity consumption has increased.

The increased electricity consumption due to the changes in the cooking patterns make it difficult to see the results of the energy saving measures through the replacement of inefficient lamps, refrigerators and fans in the electricity consumption statistics. But the increase of electricity consumption visible in the statistics is assumed to be much less than if the shift to electric cooking devices would have been carried out without the energy efficiency and saving measures. The annual electricity savings have been estimated to be 354 million kWh for the shift to energy saving lamps, and 1 147,5 million for the replacement of old refrigerators (Seifried 2013).

It has been counted that only in 2006–2007 Cuba saved over 961,000 tonnes of imported oil through the different energy saving measures, including energy conservation and the improvements in the transmission and distribution networks (Guevara-Stone 2009). And although not to be counted entirely as a result of these measures, it is notable that between 2005 and 2007 the CO_2 emissions were reduced by 18% of the emissions of the country in 2002 (approx. 5 million tons) (Avila 2008). One aspect to consider here is the

general shift of the Cuban economy from industrial production to service sector due to which the country's energy intensity in overall has been decreasing.

The energy revolution has also been referred to as a good example of environmental policy which addressed environmental justice (Bell 2011). The household appliances were of no-cost or low-cost to all, the supporting social credit system was tailored according to the income level of the households and the new electricity tariff was clearly a progressive one (the electricity price increases with increasing consumption). There have been also health benefits from phasing out the kerosene use in the Cuban kitchens.

In the industrial energy use the energy revolution measures cannot be seen as clearly as in the residential sector. The main conclusion thus is that while the energy saving measures have been quite successful in the residential energy consumption, a lot remains to be done in the industrial consumption. Also the country's overall energy mix remains to be still largely unaltered. Thus the results in terms of incorporating more renewable energy technologies into the country's energy portfolio have been far less concrete than the results from energy conservation, the rehabilitation of the national grid and the generalisation of distributed energy.

4. RENEWABLE ENERGY IN CUBA: CURRENT STATE AND FUTURE POTENTIAL

Fidel Castro called attention to renewable energy and energy efficiency as early as in 1981, in Congress on Energy. In 1985 a program was launched to develop small-scale hydropower. In 1986 a National Energy Commission was formed to coordinate energy development and to implement renewable energy and energy efficiency measures. But this Commission disappeared in 1994. As discussed above, both the National Energy Sources Development Programme (1993) and the programmes of the Energy Revolution (2006) included emphasis on renewable energy.

Thus far renewable energy has played an important role as part of off-grid small-scale electrification for remote areas. Cuba has been proud of its success in using alternative energy to bring electricity to remote and isolated regions (e.g. Rodriguez 2012). Around 10 000 households have got electricity due to these measures and if the electrified schools, health clinics and community buildings are counted approximately 34 900 people have benefitted from renewable off-grid energy (Suarez et al. 2012). In areas such as Isla de Juventud, and in the municipalities of Guamá and Bartolomé Maso the renewables form the key source of electricity (Avila 2008). Yet, the country's overall energy mix still remains to be dominated by fossils. In 2010 about 20 per cent of the primary energy was produced by renewable energy sources, and about 4 per cent of electricity was produced from renewable energy (Suarez et al. 2012). According to the interviewed Cuban energy experts the figure in electricity production has been increasing, and would be now around 7-8%. This is still very modest. Especially if compared to the strong political will in the country and the high potential in harvesting different renewable energy sources and the human resources available in Cuba.

According to the interviewed experts it would be feasible for Cuba to have 25% of electricity produced by renewable sources by 2020 if right measures would be taken. In terms of pure volume, the main renewable energy source used in Cuba remains to be sugarcane bagasse. As discussed already above it has decreased considerably after 1990 (see Fig. 2) due to the reduction of sugar production. Yet, there remains to be a considerable potential for biomass based electricity production using distributed generation, especially for the off-grid areas (Jimenez et al. 2012). Other renewable energy sources include e.g. hydro power and solar energy. There is also considerably large wind potential in Cuba (e.g. Chadee & Clarke 2014), but it is still almost totally unused. In the following sections the different options and potentials are discussed in more detail.

Box 2. Renewable energy figures in Cuba.

Installed units:
9624 solar panels
6447 solar heaters
173 hydroelectric plants, 31 of which are grid-connected
57 turbo generators and 67 boilers in 61 sugar mills
18 larger biodigesters; 300 middle sized and 600 small privately owned biodigesters (out of which very few are functional)
4 small wind farms

Potential:
1000-2000 MW potential for wind energy
Solar potential could be much higher than the wind energy potential
New boost in sugar industry could increase the potential for power generation based on bagasse and other sugarcane byproducts. Highest figure given for the potential is 3000 MW.

Sources: Grogg 2012, BBC 17.1.2011, Guillermo Leiva Viamonte's Presentation, 3 Nov 2011, Chadee & Clarke 2014.

Biomass from Agro-residues

Bagasse

Sugar cane biomass, bagasse is still the most used renewable energy source in Cuba. In primary production it counts for 16–20% of the energy produced. In electricity production in 2009 bagasse provided around 3% of total production contributing around 80% of renewable electricity production. Bagasse is mainly used to meet the energy demand required during the sugar and ethanol manufacturing process. Around 5% of the energy produced is fed into the grid. The modern sugarcane agro-industry does not utilize the energy potential of sugarcane agricultural residues which are burned before the harvest in order to facilitate the harvesting of cane stalks.

In the first half of the 20th century, Cuba was the leading sugar exporter in the world. However, since the collapse of the Soviet Union in 1991 the situation of Cuban sugarcane agro-industry has deteriorated significantly because Cuba lost its traditional sugar markets. In fact since 2003 Cuba has had to import sugar in order to meet the domestic consumption and to fulfil the export contracts. (Alonso-Pippo et al. 2008, 2163) Since 2011 there have been some signs of revival of the sugar industry (Grogg 2012, BBC 2011). Some see still remarkable potential for this sector in the energy production. Nelson Labrada, the Cuban government's vice minister of sugar has stated that "In Cuba it is possible via the sugar mills and bagasse based power plants to generate up to 40% of the energy needs of the country today" (BBC 2011).

Other agro-industrial-residues: Rice and saw mills

The overall potential for other agro-industrial-residues is much smaller than the one for bagasse (rice husk approx. 3% and saw dust around 0.15% of the bagasse potential – Suarez et al. 2012). Yet, in some regions

and communities they could provide a sustainable option. The plans to generate electricity from rice husk and feed it to the grid are still in pilot stage. Experts in Cubaenergía consider that this could be a beneficial option for at least 40 rice mills in the country. One option is that the municipalities could take the responsibility for storing rice husk. The problem is in the limited access to required technology and financing.
In terms of saw mills the gasification technology would not only provide a source for renewable energy but also a solution for the environmental problems the mills are causing. Potential for saw mills could be around 17-18 megawatts – this is not the total potential but the potential for strategic use i.e. mainly for isolated areas where the grid quality is bad and the communities would benefit from better quality of electricity services. Currently 5 saw mills are developing the use of residues for energy production.

Box 3. Cubaenergía and biomass gasification in Isla de Juventud: Example of South-South cooperation.

Cubaenergía is one of the most important research organisations on renewable energy in Cuba. It has over 90 people working on renewable energy and energy efficiency. It supports decision-makers and industry by carrying out assessments on the renewable energy potential and energy efficiency measures for different actors. It also works on provincial level and aims to support different renewable energy groups.

As part of its more local-level activities Cubaenergía carries out **pilot projects in Isla de Juventud** which explores the possibilities to use biomass gasification for rural electrification. It is seen as one of the promising ways to electrify remote areas that still lack stable access to electricity. The project builds on cooperation with an Indian company Ankur which is based in Bangalore and with a Bangalore Research Institute. Initially there was a Canadian candidate company, but as some of the parts it uses in its system are from the US, it turned out to be an impossible option because of the embargo.

Interestingly, biomass gasifiers of Ankur can also be found from other Southern countries. For example an NGO working in Cambodia called SME, which later has been turned into a company, cooperated with Ankur and imported gasifiers to Cambodia which have been then widely used in the country to produce electricity for Cambodian rice mills and also to electrify rural communities.

One challenge in the projects in Isla de Juventud has been the history of previous home-made experiments with gasifiers which did not work well. "So, we have to convince the people first and demonstrate that this technology really is different from their past experiences", comments an expert from Cubaenergía. "Also, we have had some issues with the local operator of diesel generators as he is concerned in losing his business in and thus tries to spread rumours that the gasification systems do not work. So here we have a small-scale example of how the fuel sector may try to make delays for the renewable energy."

Wood-based biomass: invasive species and tree plantations

Marabú

Picture 3. Marabú shrubs.

Cuba's agricultural sector has faced numerous challenges. The state grip over the agriculture has been strong and state has a hold on 75% of the agricultural land. Because of the inefficiencies in the system, large proportions of this land (in 2007 45%) have been lying idle and much of this land has been taken over by a plant called marabú which is an exotic invasive species. The origin of marabú is not clear: some say it was brought to Cuba as an ornamental plant, others say it was used as a fence in farms. What is clear is that it has spread all over the country and that this evasion has been difficult to control. Now that the grazing area of cattle has been shrinking it is especially these previous grazing areas that the marabou has taken over.

This is to say that whereas in several other countries the mere shortage of biomass is the main barrier in producing biomass energy, this is not the case in Cuba. Around 2 million hectares in Cuba is covered by the woody shrubs of marabú. It has been used for charcoal production, including charcoal for activated carbon which is exported to Italy and France. But mostly the marabú is not in any productive use. There are experts e.g. in Cubaenergía who want to turn this menace into a source of renewable energy. The potential has been noted to be remarkable. Cubaenergía has calculated that around 900 000 or million tonnes of marabú could be harvested yearly. According to Cubaenergía one fifth of the area now covered by marabú could be maintained for biomass production with marabú or some other suitable species. And the rest should be transformed in to agricultural area for food production. In this way altogether 4% of the country's land cover could be reserved for energy production.

A significant barrier is the problem of how to efficiently harvest these thorny bushes that grow in isolated areas. Already one British company has ventured in financing a 30 MW power plant to be fed by

marabú even though the harvesting problem still remains to be solved (Ravsberg 2010). The same company sees that in the future the generating capacities of sugar mills could be used in the marabou-based electricity production as the mills are often standing still in the summer season which is the peak time of the electricity demand in residential use (BBC 2011).

Tree plantations

Current forest cover in Cuba is around 24,5%, and the government views that it should be at 28%. In the National Environmental Strategy there are planned actions to address deforestation, restore forests especially in mountainous areas (this relates also to government targets to protect watersheds) and improve overall forest management. The strategy also includes provisions to increase forested areas for power generation. (Suarez et al. 2012) Proposals have been made to grow eucalyptus, acacia or leucaena for energy production. There are also studies and investigations going on the use of indigenous Cuban species. It has been thought that these could form a solution for some rural areas for local electricity production. But the overall concern is that these would be a very work intensive form of electricity production. In addition there have been interests to plant jathropa up to 200 000 hectares in degraded areas for biodiesel production. Thus far only some demonstration sites have been planted. The government is also aware of the global discussions on how energy production is competing with food production. It doesn't want to make energy production to compete with food production. Currently only about 30% of potential agricultural land is in productive use. Cuba is still heavily dependent on imported foods so there is a need to develop the local food production.

Biogas

The first programs of biodigesters date back to the 1970's (targeting then mainly cattle farms), but most of these old systems have been abandoned. There is a considerable potential for biogas from pig farms in Cuba which form the main meat production industry of the country. There are already some units that are using biogas for cooking and heating of water. But for big units things have been stalled in a piloting stage. There are no farms yet that would have used biogas as a source for power production.

Picture 4. Biogas plant at a pig farm.

Accurate figures are difficult to find. Some state that there are 554 units of biodigesters, others that there are 18 larger biodigesters, 300 middle sized and 600 small privately owned biodigesters. In any case several units seem to be out of use due to e.g. maintenance problems or lack of materials. For example in the province of Pinar del Rio in 2010 there was 85 biodigesters out of which only 34 (40%) were functioning (Galvez 2013).

Cubaenergía is making investigations on developing biogas solutions for middle-sized pig farms (around 5000 heads of pigs). In small-scale solutions there is positive experience with Canadian cooperation that is targeting 200 farms with 12 cubic meter unit size.

There are some governance challenges that would need to be solved to enable biogas to be used in full potential in the pig industry. Until 1994 most of the swine production was in the hands of the state. In 1994–95 new cooperatives emerged. Still mostly farmers produce the meat but the genetics and breeding is taken care by state. So farmer is responsible for producing the meat but the state is responsible for the breeding and genetics.

There is also biogas potential for agricultural waste and the food processing facilities. Here the opportunity is that farmers often know in advance what they will sell as the producers make contracts before hand – so this would allow planning also for biogas usage. The challenges include e.g. lack of construction materials, as currently the plant construction would be competing with house construction materials. One solution could be that the municipality would be responsible for a program to get construction materials specifically for this purpose.

Solar energy: PVs for isolated areas, heaters in the rooftops around the country

The successes in bringing electricity to rural populations by solar PVs have been already discussed above. There is currently at least around 10 000 units installed in the country. According to Suarez et al. (2012) the total installed capacity was around 1,8 MW in 2009 but it is increasing rapidly. A key characteristic in the Cuban PV-programs has been that first schools and health centres are prioritized and then the next step is to target private households. In 2011 there were about 7100 stand-alone PV systems that have been installed for schools, health clinics and community centres. In comparison many programs in the developing countries, like e.g. the World Bank and GEF funded rural electrification programs, have often targeted private households providing them solar home systems (e.g. Käkönen & Kaisti 2012).

In Cuban programs of PVs to rural schools two types of sets have been used: one that enables the use of TV and videos and if the school has more than 50 students then a larger set is provided which enables also computer use. The electrified medical posts often form also village centres. The electrified social centres provide often e.g. common use refrigerators. The maintenance of the rural PV sets is organized by the government. The interviewed experts stated that "it is not excellent but still decent". Every province reports monthly how many sets are not working and then an entity called Copestel should take care of repairing them. As mentioned earlier an NGO Cubasolar has been also very active in providing different solar solutions.

Box 4. Cubasolar: Pioneering and fostering the renewables in the country.

Cubasolar is one of the most relevant actors in the field of renewable energy in Cuba. It is an NGO promoting the use of solar and other renewable energy sources and also implementing several projects. It is run by engineers, scientists and planners who have been crucial for the sector of renewables in the country. It disseminates information, organizes trainings and tries to create networking amongst the different actors of the sector. It publishes a scientific magazine "Energía y Tu" with four issues per year on renewable energy (see http://www.cubasolar.cu/biblioteca/energiaytu.asp).

Cubasolar: www.cubasolar.cu

One key aspect in Cuba is the development of local assembling and manufacturing capabilities that has made the PV panels more affordable. After years of research, in 2001 the Pinar del Río Electronic Components Complex managed to begin production of a panel model where it manufactures 70% of the materials and 30% of panel material is imported from Europe. This has been calculated to save around 10% of costs compared to panels that would be completely imported. (Barclay 2003.)

All in all the solar power potential is high in Cuba and only tiny fraction of it is currently in use. Thus far they have been used only for remote off-grid areas. But things are about to change. Although not yet visible in the statistics, the solar PV capacity has increased considerably and there are plans to rapidly increase it further. Cuba's first solar farm opened in spring 2013 in Cantarana. It boasts 14,000 photovoltaic

panels with the capacity of 2,6 MWp, which in a stroke more than doubled the country's capacity to harvest energy from the sun. The government financed the construction, and the panels were manufactured at a factory in the western province of Pinar del Rio. Six other solar parks are planned to come online soon. The Santa Teresa-Los Güiros park in Guantánamo, with 10,800 panels on 5 hectares, was planned to start operating in December 2013.

Yet, a lot remains to be done especially with supporting institutional structures, so that the solar electricity would become more mainstreamed option and also viable in the urban areas. For example a feed-in remuneration for solar electricity would still need to be developed.

Picture 5. Solar panels in Cantarana (Photo by International Rivers).

Solar heaters

Solar water heaters were introduced in Cuba very early, according to Avila (2008) in the 1930s. But they have become more widely used in the past three decades. According to Suarez et al. (2012) in 2009 at least 8000 solar water heaters are used in hotels, hospitals and schools amounting to 3,8 MW of installed capacity and an annual saving of 935 toe.

Many groups are working on developing practical solar cookers and solar dryers. Some NGOs e.g. from Canada and Austria have been supporting this work. For example Centro de Investigaciones de Energía Solar (CIES) has been developing new low-cost models but the scale-up would need further finance or support (See Box 5. for CIES).

Picture 6. Centro de Investigaciones de Energía Solar (CIES)

Box 5. Centro de Investigaciones de Energía Solar (CIES) – Long term renewable energy research but little funding.

Cuba has been interested to develop renewable energy long before the Energy Revolution began in 2006. Solar energy research centre **Centro de Investigaciones de Energía Solar** (CIES) in Santiago de Cuba is one of the leading renewable energy research centres in Cuba, but it is suffering from the lack of funding. CIES was established in Santiago de Cuba in 1984, but its origins dates back already to the 1970's. Probably as a reaction to the first global oil crises, the Department of Solar Energy was established in 1976 under the Academy of Sciences of Cuba. It Department of Solar Energy was founded in Havana to develop renewable energy production, especially solar energy. Few years later the Department of Solar Energy decided to create a research centre in the city of Santiago de Cuba. This was the beginning for CIES.

The objective of CIES is to foster the energy saving as well as to develop the scientific and technical capacity in the provinces. The first experimental laboratory of CIES was completed in 1984, and since then the research centre has done pioneering work in building several prototypes including PV controllers, solar energy water heaters, solar kitchens, solar dryers and other appliances. It also organises workshops and provides training in renewable energy. Currently the Centre works on four different areas of renewable energy: Photovoltaic solar energy, wind energy, solar power and solar biotechnology. CIES is currently under the Ministry of Science, Technology and Environment (CITMA). It has a national mission to investigate, produce and market integrated sustainable technologies, to provide and disseminate expertise, and to offer technical services in order to extend the use of renewable energy.

There are more than 100 people working in CIES but it is affected by limited funding. There are numerous prototypes of appliances that use solar energy but are no longer functioning due to lack of funds. Some of the prototypes lie outside on the ground, grass pushing through. Some buildings remain unfinished, and only part of the laboratories are actively used.

Despite of its financial difficulties, it is still developing new technologies and it has for example provided 360 solar PV stations to schools, social service centres and other public organisations. It has also built 300 windmills that are used for pumping water, and dozens of solar water heaters and sun dryers. CIES has developed low-cost solar driers as well as proto-type models with automatic control and energy storage that could become competitive with scale-up projects. It is also organising maintenance workshops for communities and other end-users. One of its main achievements has been to develop renewable energy systems that are easily maintained by the community. Perhaps even more importantly the researchers in CIES have been successful in developing batteries that – with careful maintenance – have already functioned for 13 years. The lifespan of the solar PV batteries is often relatively short, and the replacement is expensive for many users that rely on solar energy in the developing countries. The long-lasting batteries and the organisation of maintenance workshops both increase the lifespan of renewable energy appliances and sustainability of the renewable energy solutions.

CIES website: http://www.santiago.cu/hosting/cies/cies.htm

Wind

The first wind park was installed in 1996 by Cubasolar with turbines from Spain. The funding came mainly through international NGOs. For a long time it was the only one. Interestingly, some say that it was actually the Guantanamo Base that had a significant role in sparking the wind energy discussion in Cuba. When Cubans found out that the Base was self-sufficient in energy by using wind energy there was a clear increase in interest for developing the wind energy sector. Currently there are three more small wind parks, funded by the government. The four wind parks consist of 20 turbines with total installed capacity of 11,2 MW. The potential for the wind energy seem to be very significant, at the same time risks of hurricanes, flooding etc. also have to be carefully considered. Risoe from Denmark has provided support for the first wind energy map in Cuba. Also investigations have been carried out with assistance from meteorological stations. Currently at least 20 suitable sites have been identified. According to an energy expert Leiva Viamonte (presentation 3.11.2011) the wind power potential is around 2000 MW out of which 1200-1800 MW would be feasible to install by 2020. The main overall challenge to materialize this relates to the difficulties in attracting investments. The highest figures on the overall potential go up to 5000 and 14 000 MW (Avila 2009), but the feasibility studies for these high figures seem not to be in a very detailed level. For small-scale turbines (e.g. for rural areas) the difficulty remains with the high up-front costs. Some initial discussion has been there to consider whether Cuba could develop its own low cost models. This remains to be seen.

Wind mills for water pumping

Wind energy for water pumping is commonly used in the rural areas. Cubans have also developed their own low-cost models for small turbines. Figures of the scale of production and usage are hard to find. According to Suarez et al. 2012 there are more than 4850 windmills installed and the Ministry of Sugar has announced a plan to double the future installations.

Picture 7. Wind pump.

Hydropower

The overall installed capacity of hydropower in 2009 was 58 MW (Suarez et al. 2012) and it counted for approximately 15% of the renewables used for electricity production. In 2011 the installed capacity was estimated to be around 65 MW (Presentation by Avila 1.11.2011). The number of constructed units ranges in different sources from 173 to 180. Around 30 of them are connected to the grid and the rest are isolated systems in off-grid areas (ibid.). It has been estimated that around 35 000 people have benefitted in getting access to electricity from these systems. Around 100 of the plants are mini or micro hydropower stations. A major problem is that many of them do not operate the whole year around resulting in "seasonal black-outs" and many of them are not able to offer stable and good quality electricity supply. There seems to be also maintenance and management issues with small-scale hydropower. Initially Institute of Water Resources was in charge of the management and maintenance, then the responsibilities were shifted to a company and then to power utility.

For the rural areas there seems to be unharnessed potential in several existing small dams that are built purely for water control purposes (and not for electricity production) but could be turned into power stations with rather low investment costs.

The overall potential in the country has been estimated to be around 650 MW, i.e. only 10 % of this is currently harnessed. Then again half of the potential lie in protected regions with high biodiversity value which has been said as one of the reasons why hydropower has not been developed in larger scales (Avila 2008).

Other

Other renewable energy sources are still mainly on a stage of research. This goes for example for geothermal and ocean energy. Tide currents, wave energy and ocean thermal energy conversion (OTEC) could all be options for Cuba, island state as it is. In fact the first Ocean Thermal Energy Conversion power plant in the world was developed and installed in Cuba, in Matanzas Bay in 1930 by two French scientists (Avila 2008). Although it was abandoned there is active research in Cuba on the future OTEC options.

5. CHALLENGES IN SUSTAINABLE/RENEWABLE ENERGY DEVELOPMENT

Difficulties in obtaining technologies and supplies from abroad together with limited possibilities in having access to international credits

The challenges that have slowed down the development in renewables are several. In the Cuban context geopolitics matter. The US embargo is one issue that creates difficulties in obtaining technologies and supplies from abroad. Cubans have tried to overcome this partly by developing local capabilities to manufacture energy equipment and spare parts, but shortages in basic materials and lack of financial support are significant. Cuba has currently very limited access to international credits. It also has difficulties in getting foreign investments.

Governance and institutional structures: 'Some currents, but not the whole river'

Many interviewed experts also highlighted the gaps in the current governance structure and a lack of clear national strategy with strong targets. As explained in previous sections, Cuban government has realized and emphasised the priority as well the necessity of increasing the share of renewable energy resources into the nation's energy matrix. As one interviewed expert commented: "Although the president and prime minister have signalled strong support for renewable energy development, the governance measures remain underdeveloped. Some currents are there, but not the whole river". Currently a nation-wide energy policy, for introducing and fostering the usage of renewables, is under assessment and approval procedures by the different Ministries and State Councils. It seems that also new legislation and financial mechanisms would be needed. For example a regulatory framework for investments in renewable energy technologies is currently under-developed. And there is no policy in place to create monetary incentives for Cuban actors in strengthening the use of renewables.

Another expert commented that the energy sector is lacking clear authority: "There is no national coordinating body dedicated to energy, renewable energy and energy efficiency. Maybe what we need is a Ministry of Energy". Currently different renewable technologies are under different governmental actors, institutions and ministries. The current institutional set up of Nation-wide Groups on Renewable Energy, Cogeneration, Energy Saving and Energy Efficiency (formed in 2006) was perceived as not solid enough a structure.

Concerning the state-led programmes one challenge is that public criticism is not welcome in Cuba. This may hinder constructive feed-back. Thus it may take longer times to address the possible shortcomings of the programs and lower the chances for re-adjustments and corrective measures.

Energy efficiency not yet translated into savings in the productive sector

The measures of energy efficiency in household level have been relatively successful. But in the productive and service sector there is still a lot of work to be done. There should be mechanisms set in place for energy service companies to benefit from energy savings made by their customers. As one expert commented: "Specialised mechanisms should be developed to turn 'negawatts' into a business opportunity".

Role of local governments

The local governments could also be encouraged to have more active role. This was the view of all interviewed experts. Currently they were perceived as having limited knowledge on renewables and no motivation for facing risks related to the alternative technologies. The current distributed system would work better if municipalities could play a more significant role in the energy sector and if they would be incentivised to promote renewable energy solutions. There should be mechanisms built so that the municipalities could actually also benefit from the renewable energy solutions. For example if part of the taxes would go straight to the budget of the host municipality. There are often also attitude issues that should be overcome. For example the experiences with the past forced trials of alternatives in the "special period" that did not work because of low quality materials still create suspicion for the new initiatives e.g. with renewable energy systems based on biomass or biogas.

> For donors such as the European Commission there would be plenty of opportunities in Cuba for cooperation in supporting and fostering the agenda of sustainable energy for all.

There are lot of statistics on energy production in nation-scale but there is almost no data on community level which would be crucial for designing distributed systems powered by renewable energy. It would be important to make local resources and conditions more visible so that designs could be made based on local strengths.

6. CONCLUSIONS: WHAT TO LEARN FROM THE CUBAN CASE

This report has described how Cuba has been moving towards a new more sustainable energy paradigm. This has been motivated not so much by environmental concerns but out of necessity caused by economic crisis, shortages of imported oil, poorly functioning old power plants and hurricanes. Since 2006 Cuba has shifted from centralized to more distributed energy system and impressive rates of domestic inefficient electric appliances have been replaced with more efficient equipment. Cuba has been one of the first countries in the world to completely shift from incandescent bulbs to compact fluorescent lamps. It has also emphasized the importance of renewable energy from very early on and succeeded in providing electricity to rural areas often through renewable sources. Yet, the country's overall energy system still relies largely on fossil fuels.

Cuba has both natural and human resources needed for a new sustainable energy pathway that would be based more on renewable energy. Cuba has highly qualified scientists and experts on renewables and sustainable energy as well as high-level government support for sustainable energy production and use (see Annex 2 for the list of organisations with expertise on renewable energy). The major barrier is formed by limited access to finance. For donors such as the European Commission there would be plenty of opportunities in Cuba for cooperation in supporting and fostering the agenda of sustainable energy for all.

Despite the lack of materials and finance, Cuba has managed to assimilate many foreign energy technologies and developed also its own appropriate technologies especially in the sugar industry's bagasse use, solar energy applications (including different models of heaters and driers) and mini- and micro hydropower solutions. The past experiences have built also expertise that could be beneficial for different forms of South-South and North-South-South cooperation. One area is the development of low-cost, appropriate renewable energy solutions. Another area is the deployment of renewable energy in electrifying remote rural areas in which Cuba is one of the most advanced in the Caribbean region. Cuba has also had strong social goals in its electrification programs as it has been prioritizing schools and health centers as well as communal and cultural centers. Cuban experiences are thus valuable for all projects and policies aiming for electrification in support of social goals.

> Cuban experiences could be beneficial for South-South and North-South-South cooperation in areas of low-cost appropriate renewable energy solutions, deployment of renewable energy in electrifying remote areas, electrification programs with social goals, and when developing sustainable energy policies with social fairness elements.

Cuba has been compelled to explore ways to foster energy efficiency. Cuban energy conservation efforts would deserve more international attention and valuable lessons could be learnt from them. Again here, interesting elements relate to the social components and social fairness considerations of the program. The new electricity tariff is clearly a progressive one, so that there is incentive to save electricity but without making the poorest households to suffer from larger electricity bills. Several social workers were involved in the energy revolutions programs, the distribution of energy saving lamps and fans was done free of charge,

and the credit system to support households in purchasing more costly appliances such as refrigerators was adjusted to the household's income level and repayment capacity.

As one interviewed expert commented: "People have often asked me, for example people from Brazil and Australia, that could this work in a democracy? There is no easy answer. But I often refer to Denmark: they are a democracy but also very progressive and efficient in their energy reform. So I guess it is more about political will and clever social organization than about anything else." The strict central directives and forced conversion through which the appliance replacement program in the Energy Revolution was partly achieved are not something to be replicated e.g. in the European countries. There is, however, something to be learnt from the decisiveness of the energy efficiency programs and also from its social fairness elements. Lessons from Cuban experiences are interesting, especially when considering sustainable energy policies that do not impact negatively the low-income households.

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ANNEX 1.
INTERVIEWED EXPERTS AND RESOURCE PERSONS

Daniel López Aldama	Cubaenergía (Director)
Dr. Oscar Jimenez	Cubaenergía (Expert in bioenergy)
Dr. Alfredo Curbelo	Cubaenergía
Yoel Suarez	Cubaenergía (Expert in biomass energy)
Mario Alberto Arrastía Avila	Cubaenergía/Cuba Solar (Expert in Energy revolution and energy education)
Dr. Iván Relova	CITMA, Ministry of Science, Technology and Environment (Expert in solar technologies)
Guillermo Leyva Viamonte	Empresa de Ingeniería y Proyectos para la Electricidad (INEL)
Prof. Jorge Bonzon	Director of Grupo de Energías Rneovables (GERA), University of Oriente
Prof. Luis Vázquez	Seisdedos, University of Oriente, Santiago de Cuba (Expert in biomass energy)
Prof. Julio García	Dean of Electrical Engineering, University of Oriente
Prof. Alexis Mora	Dean of Mechanical Engineering, University of Oriente

ANNEX 2. CUBAN ORGANISATIONS WITH EXPERTISE ON RENEWABLE ENERGY AND ENERGY EFFICIENCY

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