Renewable Energy for Development

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Cuba's Transition away from Fossil Fuels

by Dr. Antonio Valdes, Agency for Science and Technology, Havana, Cuba

In recent years, Cuba has increased efforts to exploit renewable energy sources and reduce its dependence on oil. Wind, solar, and biomass offer a variety of renewable options that are well suited to the Caribbean climate. This article discusses Cuba's current energy system, with an emphasis on electricity generation, and describes plans for expanding and improving Cuba's emerging portfolio of renewable energy options.

Cuba is a Caribbean island with a tropical climate, a landmass of 110,000 km^2 and a population of 11 million. The economy is agriculturally based, with major export products being sugar, tobacco, coffee, and citrus fruits. Nickel mining and tourism are also major components of the economy. The sunny and windy Caribbean climate and Cuba's special history of sugarcane production suggests many opportunities for tapping renewable energy resources.

Before the fall of the Soviet Union, subsidised oil and preferential trading relations with the communist world discouraged Cuba's renewable energy development. In the post-Soviet era, Cuba has had to look for new economic alternatives, including new sources of energy. The government formed the Cuban National Program for the Development of Natural Energy Resources, whose objectives are to reduce petroleum dependence by improving efficiency and developing other natural energy resources.

Most of the population (approximately 95 %) has access to electricity. Table 1 lists the current shares of different sources in electricity production and installed generating capacity. Oil remains the primary fuel in the electricity mix. The existing installed capacity in the sugar cane sector provides the best near-term option for replacing oil. Other renewables, such as wind, hydro, and solar can play an important role as well.

Solar Energy

Solar insolation in Cuba averages 5 kWh/m^2/day with little seasonal variation, and is currently used for both Photovoltaic (PV) and solar thermal applications. Solar thermal is used for water heating in the residential sector and in larger social institutions, such as nurseries, hospitals, and schools. PV systems are used in remote rural areas with poor access to the national electricity grid, including hospitals, schools, and tourist sites as well as homes (see photo). There exist approximately 1000 PV installations ranging in size from 10 W to 90 kW, for a total installed capacity of 202 kW. Some of these PV installations have special social significance, such as those at the 225 General Practitioner Doctor Dispensaries located in the sparsely populated inland hills. A typical installation is a 400 W system that powers twelve fluorescent lamps, a TV set, a radio transmitter, three medical instruments, and a small refrigerator for vaccines.

Solar PV Installation in rural Cuba

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Wind Power

In Cuba, wind energy is today mainly used for water pumping, with over 6 700 wind-powered pumps currently in operation. Wind has not yet been significantly exploited for power generation.

At present there exist only two systems – a system of two 225 kW turbines on Turiguano Island (see photo) – and an experimental 10 kW turbine at Cape Cruz. At Turiguano Island, there are plans to expand to 1000 kW – enough capacity to supply 40 % of the island's electricity needs and displace 430 tonnes of fuel oil per year. A recent survey at over 20 sites, primarily in coastal regions, concluded that there are excellent possibilities to develop wind power at these sites.

Wind Installation in rural Cuba

Hydropower

Hydropower plants are classified by their rated capacity into one of four regimes: micro (< 50 kW); mini (50–500 kW); small (500 kW–5 MW); and large (> 5 MW). Cuba's current installed hydropower capacity amounts to nearly 30 MW, which in 1998 produced 23 GWh of electricity. The number of hydropower plants in the three smaller categories are given in Table 2, accounting for about half of total hydro capacity in Cuba. These plants are generally used to service 200 small, isolated, rural villages with over 7 000 houses and 24 000 inhabitants. The plants also provide power to 503 social service institutions. There are also 6,6 MW under construction, capable of supplying an additional 38 GWh per year. Estimates of Cuba's hydro potential that remains to be exploited range from 50 MW (210 GWh/year) to 400 MW (1 000 GWh/year).

Biomass Resources

Biomass resources should be divided into residues or dedicated resources, the latter including fuelwood and charcoal from forest resources. Approximately three million m^3 of fuelwood are consumed per year, mainly for cooking. To avoid resource depletion, Cuba is currently undergoing a reforestation program of 130,000 ha. Biomass residues are more economically exploitable and more environmentally benign than dedicated biomass resources. There exist a variety of readily available sources in Cuba, including agricultural residues such as sugar cane bagasse, rice husks, and coffee residuals; tree/forest residuals such as sawdust and coconut shells; and various animal wastes.

Sugar Cane Biomass

Residuals from the sugar cane industry represent by far the most important source of current and potential biomass resources in Cuba. The sugar industry in Cuba goes back hundreds of years and Cuba has been one of the world's leading sugar producers since the 1800s. Sugar cane plantations cover one-fourth of the arable land in Cuba, and Cuba accounts for 10 % of world sugar cane production. In addition to raw sugar, Cuban enterprises produce and utilise many valuable cane co-products for feed, food, energy and fibre. At present, there are 156 sugar factories, 16 sugar refineries, 13 alcohol distilleries, 10 Torula yeast plants, 5 pulp and paper plants, 7 particle board plants, and 160 animal feed production plants.

Table 3 illustrates the development of cogeneration within the Cuban sugar industry. Installed capacity doubled between 1959 and 1990, while electricity generation tripled. Sugar cane bagasse and sugar cane trash already provide a significant amount of biomass for electricity production in Cuba, but the potential is much higher with advanced cogeneration technologies. Most sugar factories in Cuba, as elsewhere in the developing world, can produce about 15-30 kWh per tonne of cane. If all factories were fitted with Biomass Gasifier-Combined Cycle systems, 400–800 kWh of electricity could be produced per tonne

Table 1: Electric Power Fuel Shares in Cuba

	Electricity Production	Installed Capacity
Petroleum	87 %	
Diesel		1 %
Oil		72 %
Cane	5 %	19 %
Hydro	2 %	1 %
Gas	6 %	6 %

Table 2: Smaller-scale Hydroelectric Plants installed in Cuba

Type of hydro installation	Number of plants Installed	Number connected to grid	Number of isolated installations	Installed power (kW)
Microplants	138	9	129	3 033
Miniplants	32	12	20	4 030
Small plants	5	5	–	7 310
Total	**175**	**26**	**149**	**14 373**

of cane, enough to satisfy all of Cuba's current electricity demand.

Alcohol production

Cuba has 13 alcohol distilleries with capacity of 200–1200 litres/day that use cane molasses as feedstock, for a combined capacity of over 1,5 million hectolitres. The alcohol is used for a variety of applications, mainly for medical purposes and rum production, the latter of which accounts for 74 % of domestic use. Use of alcohol fuels, once common in Cuba in the 1940s and 1950s, all but disappeared with the availability of cheap oil. The current circumstances suggest that Cuba should consider expanding production for use as a transportation fuel, but this option has not yet been pursued. Blending with gasoline would also have direct environmental advantages by substituting for lead as an octane enhancer.

Biogas

Presently, Cuba uses a significant amount of kerosene, diesel, firewood and charcoal for cooking in many rural areas. Anaerobic digesters producing biogas (methane) offer a sustainable alternative fuel for cooking that is appropriate and economic in rural areas. In Cuba, there are currently over 200 installed biogas units, covering a wide range of scales appropriate to family, community, or industrial uses. The sugar and coffee industries are the main sources of feedstocks for larger scale biogas plants. Pig and cattle farming are likely sources for smaller-scale biogas; in Cuba these provide feedstocks for 75 biogas installations. Of this total, 60 units are of fixed dome design with volumes of 8 to 70 m^3, and 15 units are of plastic tubular design with volumes ranging from 12 to 24 m^3. The solid waste from biogas plants adds economic value by providing valuable fertilisers as by-products.

Rail link to the Urbano Noris sugar factory in Cuba

Table 3: Development of Cuban Sugar Industry Cogeneration

Year	1959	1990
Number of sugar factories	159	156
those with power plants	119	150
Installed Power (MW)	317	726
Generated energy (GWh)	390	1 262

Table 4: Aggregated value added for sugar co-products

Source	Indicator	Value (10^3 USD/year)	Oil equivalence (t/d)
Filter Cake (t/d)	175	–	–
Biogas (m^3/d)	7 000	112	3,4
Fertiliser (t/d)	40,3	86	–
Molasses (t/d)	150	–	–
Alcohol (t/d)	33	315	21,0
Biogas (m^3/d)	13 230	96	6,4
Fertiliser (t/d)	2,84	0,15	–
Electricity (MWh/d)	600	5 940	180,0
Sugar (t/d)	500	19 800	–
Total Value	–	26 350	210,8
Increase in Value	–	6 550	–

Economic Potential of Cane Resources

An example from a typical sugar factory in Cuba illustrates the economic value of attempts to better utilise the cane biomass resources available. Table 4 gives the quantity, estimated economic value-added, and oil equivalence for the major co-products from a factory producing 500 tonnes of sugar per day. The additional products have an estimated value of 6.55 million USD, an increase of 33% over the value of the sugar alone. The optimisation of the sugar industry is thus important not only from an energy perspective, but from an economic perspective as well, particularly given increasing competition and low and fluctuating prices for sugar.

Conclusions

Cuba's energy system is in the midst of a transition away from fossil fuels towards a more sustainable energy system based on biomass and other renewable options. Sugar cane is presently Cuba's most valuable renewable energy resource, and bagasse cogeneration offers significant opportunities for expansion in the near-term. Biogas plants also offer renewable options that are relatively inexpensive and well suited to rural areas. Hydropower has a more limited long-term potential compared to biomass options, but will continue to play a role in smaller-scale energy supply. There is also potential for expanding wind and solar applications in Cuba, particularly in coastal areas. ■

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Sudan's Renewable Energy Options:

Power for Water and Living

By Abdeen Mustafa Omer, National Company for Manufacturing Water Equipment Ltd., Sudan

The harsh climate in Sudan presents unique challenges in meeting growing demands for power and water. Among the renewable energy options that have received special attention are wind pumps and solar stills. This article provides a brief overview of efforts to expand such renewable technologies in Sudan in a cost-effective and sustainable way.

A rapid increase in the rate of population growth, economic development, urbanization, and industrialization in Sudan has led to increased demand for energy. With a current population of 26 million and annual growth rate of 2.8 %, this trend is expected to continue. Coupled with this is the growing demand for potable fresh water, which must be desalinated or pumped from the ground, presenting special challenges in the harsh and dry climate. These resource management and procurement issues are unique to Sudan and require new strategies. Renewable energy in the form of wind and tropical sunshine is abundant in Sudan, and can play a major role in Sudan's energy mix.

Energy in Sudan

Sudan meets approximately 87 % of its energy needs with biomass, while oil supplies 12 %, and the remaining 1 % is produced from hydro and thermal power. The total energy consumed is approximately 11.7 million tons of oil equivalent (TOE), with an estimated 43 % lost in the conversion process. The heavy dependence on biomass threatens the health and future of domestic forests, and the large quantities of oil purchased abroad causes Sudan to suffer from serious trade imbalances. A shift to renewables would therefore help to solve some of these problems while also providing the population with higher quality energy, which will in turn, improve living standards and help reduce poverty. Three renewable resource options that fit well with Sudan's unique resource needs and endowments are wind, solar stills, and biogas. Wind pumps and solar stills have been pursued on a wide scale in Sudan and are discussed below. The potential for biogas options is well known, but it has not yet been widely pursued.

Locally-manufactured wind pump installed at kilo 8 site

Wind Pumps

Sudan is rich in wind potential with a considerable area suitable for electricity generation and most of the country suitable for pumping water. Wind speeds between 3–5 m/s are considered sufficient for water pumping, and much of the country has average wind speeds in this range.

Forty years ago, wind pumps were very common in central Sudan, but gradually disappeared due to a lack of spare parts and maintenance skills combined with stiff competition from relatively cheap diesel pumps. However, the government has recently begun to recognize the need to reintroduce wind pump technology to reduce the country's dependence on foreign oil. This increases economic security, given high and/or fluctuating oil prices, and it helps to reduce the trade deficit. Using wind power also allows for pumping in rural areas where transportation of oil might be difficult.

In 1985, the Energy Research Institute (ERI), in cooperation with a consulting services firm, started a wind pumps project financed by the Netherlands Ministry of Foreign Affairs. During the 14 months of the project, ten imported wind pumps were installed in the Khartoum area, and one was locally manufactured for demonstration. Results suggested that for some local applications, wind energy is an economically and technically viable option.

After the termination of the project, the ERI continued monitoring and testing the performance of the installed pumps, and the consulting firm set out to produce wind pumps for low head pumping applications which could be built in developing countries.

So far, two wind pumps have been manufactured locally at a cost of US $2 500 each, and initial test results indicate that the design has room for improvement. The performance of the wind pumps was below expectations, possibly due to a low pump efficiency and high start-up wind speed (3 m/s). The amount of maintenance required was also higher than anticipated (at least once every two months).

For wind pumps to be effective and competitive, it is recommended that further research be carried out to improve overall efficiency and simplicity of the wind systems, and to incorporate locally available materials into the design. Also, quality control guidelines should be established and users trained on how to utilize the pumps more efficiently.

Solar Desalinization

Sudan enjoys bright sunshine and dry weather most of the year. The available solar energy can be utilized for water heating and desalination to replace fuelwood, which in turn eases pressures on forests and eliminates the associated pollution, along with the need to collect and transport the fuel.

The use of solar energy for desalinization is especially appropriate since the need for potable drinking water is so great, and because the areas which lack potable water supplies happen to have abundant solar and wind energies. Solar desalination was initiated in Sudan as a possible means of converting the underground brackish water into potable water to contribute to the anti-thirst campaign – especially in those isolated, arid areas lacking both fresh water and power.

Solar stills at Soba site

A solar still unit (see picture) consists of a basin, an insulating bottom layer, a black lining, and a transparent cover arranged in such a way that the surface slopes downwards and rests on a collecting trough at the sides. The design is simple in construction, operation, and maintenance, is rigid and firm enough to resist the worst environmental conditions, and attempts to use locally available materials.

The Energy Research Institute (ERI) set up a bilateral project in conjunction with the National Company for Manufacturing Water Equipment Ltd (NCMWE) in 1995, with the aim of solving the salinity problem in isolated areas. It has been undertaking research to test the performance of existing solar stills under the various prevailing operational conditions, and seeks to ultimately develop a solar still design that is economical and technically suitable for use in Sudan. Current stills can produce up to one gallon of potable water per square meter per day. Further efforts should seek to educate the public and provide incentives to encourage solar energy use in the household sector.

Conclusion

The projects conducted by the NCMWE indicate that wind pumps and solar stills can help meet increasing energy demand while also providing much-needed potable water in Sudan, especially in rural areas. The resources exist and the technology is competitive, but more investment and infrastructure (local materials and building capacity) are needed to begin to realize the full potential that these resources offer. Development of renewable energy technologies such as these, that are well-adapted to local needs in Sudan, can cost-effectively contribute to reduced dependence on foreign oil, reduction of the national deficit, increased energy availability, and to environmental benefits associated with displacing fossil fuels. ■

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Non-Conventional Energy Sources:

An Appraisal of Policies, Goals, and Achievements in India

By Dr. Atiqur Rahman, Department of Geography, A.M.U., India

India is an important case study in the context of renewable energy. It has a long history of meeting its energy needs through renewables. India's renewables portfolio is broad and diverse, due in part to the country's wide range of climates and landscapes. Like many of the world leaders in renewable energy utilization, India has a well-defined commitment to continued research, development, and implementation of new technologies. This article considers the major renewable energy options to help India meet growing energy demand.

In 1992, India created the Ministry of Non-Conventional Energy Sources (MNES) to take responsibility for all matters relating to non-conventional/renewable energy. It undertakes the role of renewable energy policy making, planning, promotion, and coordination. In recent years this agency has overseen the development of a broad base of technologies including biogas plants, solar thermal and PV systems, wind turbines, small and micro-hydropower units, energy from urban and industrial wastes, and even improved chulhas (a wood-fueled cooking place). The following sections outline the history, current status, and planned future development of these technologies. Table 1 summarizes the potential and the current status of renewable energy deployment in India.

National Biogas Development Program

Launched in 1981, this program sought to produce biogas from animal waste via anaerobic digestion, thus producing a useful energy carrier while disposing of the waste. The National Biogas Development Program has overseen the deployment and installation of 2.85 million biogas plants (as of 1999), mostly in the form of family-sized plants. It is estimated that these plants generate a fuel gas equivalent to three million tonnes of fuelwood per year, valued at 4350 million rupees.

MNES provides financial support to consumers, entrepreneurs, and NGOs in order to encourage widespread use of biogas technologies in rural areas. Current research involves adapting the technology to operate in some of India's colder climates.

Table 1: Renewable Energy Potential and Achievements in India

Source/System	Approximate potential	Status (as of 31.03.1999)
Biogas plants (No. of units)	12 million	2,85 million
Improved Chulha (No. of units)	100 millon	30 million
Solar Water-heating Systems	30 mil. m^2 collector area	450 000 m^2
Solar Photovoltaic System	20 MW/sq km	329 MW
Biomass Power	17 000 MW	
biomass gasifiers (stand-alone)		29,50 MW
biomass combustion/gasifier		37 MW
bagasse based cogeneration		134 MW
Wind Power	20 000 MW	1 025 MW
Small Hydro (up to 3 MW capacity)	10 000 MW	183 MW
Solar Photovoltaic Power		(940 KW grid) (650 KW non-grid)
Solar Cookers (No. of units)		475 000

Source: India 2000

Biomass

Direct burning of fuelwood and crop residues constitute the main usage of Indian biomass, as is the case with many developing countries. However, the direct burning of biomass in an inefficient manner causes economic loss and adversely affects human health. In order to address the problem of inefficiency, research centers around the country are have investigated the viability of converting the resource to a more useful form, namely solid briquettes and fuel gas.

Briquetting is the formation of a char (an energy-dense solid fuel source) from otherwise wasted agricultural and forestry residues. One of the disadvantages of wood fuel is that it is bulky and therefore requires the transportation of large volumes. Briquette formation allows for a more energy-dense fuel to be delivered, thus reducing the transportation cost and making the resource more competitive. It also adds some uniformity, which makes the fuel more compatible with systems that are sensitive to the specific fuel input. It is estimated that 145 million tonnes per year of surplus agricultural residue are available for briquetting, representing an equivalent of 14 GW of power equivalent.

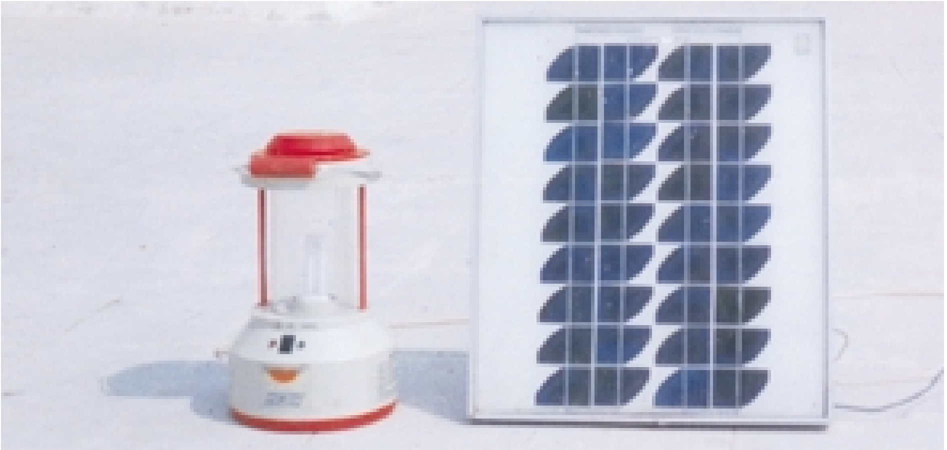
Gasification is based on the formation of a fuel gas (mostly CO and H_2) by partially oxidizing raw solid fuel at high temperatures in the presence of steam. The technology, initially developed for use with coal as a fuel input, can also make use of wood chips, coconut shells, sugarcane bagasse, rice husks, and other similar fuels. Generation capacity ranges from 3 to 500 kW for biomass systems (coal systems can be much higher). Twelve gasifier designs have been developed to make use of the diversity of fuel inputs and to meet the requirements of the product gas output (degree of cleanliness, composition, heating value, etc.).

Another large-scale use of biomass is the firing of bagasse, the waste from the sugar cane industry in cogeneration plants to supply all the required heat and power needed for sugar production, leaving enough power to sell to the national grid. A potential of 3 500 MW has been estimated while only 171 MW have been installed, with an additional 230 MW under construction.

Furthermore, India is investigating the potential to make use of more and more of its waste. Household waste, vegetable market waste, and waste from the rice, leather, and pulp and paper industries can be used to produce useful energy either by direct incineration, gasification, digestion (biogas production), fermentation, or cogeneration. As an example, a 2,75 MW rice-husk fueled power plant has been commissioned in Tanaku, Andhra Pradesh, and a 10 000 m^3 per day biogas plant using slaughter house waste is in operation in Hyderabad.

Solar Thermal

India already has a well-established solar thermal infrastructure with applications including water heating, space heating, cooking, drying, water desalinization, industrial process heat and steam generation. About 450 000 m^2 of collector area has been installed thus far, most of which is used for solar water heating and box-type solar cookers. Future developments include a proposed 140 MW integrated solar combined-cycle power plant, including a 35 MW solar thermal system at Mathama village in Jodhpur.



A Solar lantern used in the small towns and rural areas of India in the absence of electricity

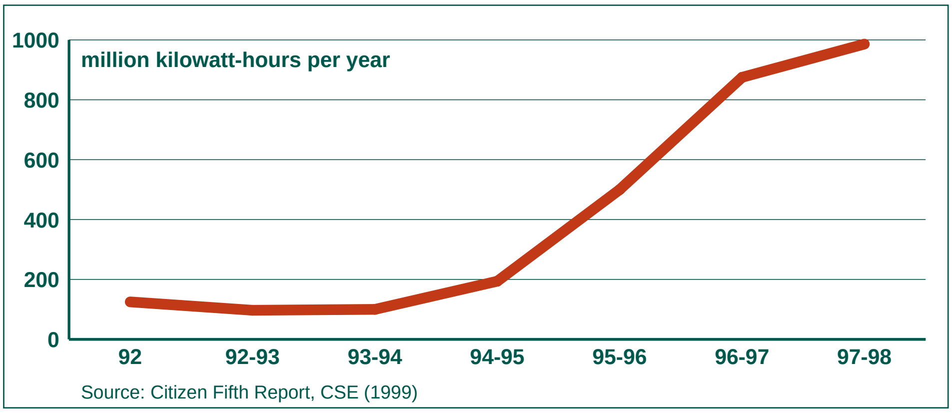
Solar Photovoltaic (PV)

PV has found its way into several niche markets in India, nearly all in rural settings. PV is used for lighting, water pumping, telecommunications, and even small power plants. Thus far over 6 million PV systems – amounting to 40 MW of capacity – have been installed, and over 300 000 homes have PV for lighting or water pumping, making India one of the top-ranking PV users in the world. A more recent trend is for rural cooperatives to purchase larger-scale PV systems for whole communities. One such system is the 26 kW power plant on Sagar Island in West Bengal, which supplies electricity to 300 households.

Wind

The installed Indian wind capacity has increased ten-fold over the last eight years to a level of 1,025 GWh (see Figure 1) out of a technically feasible 9 GWh which places India fourth in global wind power production after Germany, the US, and Denmark. This has been made possible by aggressive policy and the establishment of a domestic wind turbine industry.

Figure 1: Wind Power Generation in India



Small and Micro Hydro

Smaller-scale hydro plants (under 3 MW) are more environmentally benign than the large-scale hydro projects that often involve huge dams and permanent restructuring of the landscape. These smaller plants are perfectly suited for some regions of India where there is plenty of rainfall and a mountainous or hilly landscape such as Laddakh or the north-eastern states. Currently, India has over 180 MW of installed capacity and 150 MW more under construction.

Conclusions

In a country with a population as large and dense as India's, there are extreme pressures on energy and waste systems which can stunt the country's economic growth. However, India has recognized the potential to alleviate some of these problems by promoting renewable energy and utilizing its vast and diverse climate, landscape, and resources, and by coupling its solutions for waste disposal with its solutions for energy production. Thus, India stands at the forefront of the global renewable energy community, and presents an example of how non-conventional energy strategies may be implemented. ■

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The Stockholm Environment Institute (SEI) is an international research institute focusing on local, regional and global issues related to environment and development.

The scientific and administrative work of the Institute is co-ordinated by SEI's headquarters in Stockholm, Sweden, with centres in Boston (USA), York (UK), and Tallinn (Estonia).

In addition, SEI works with an international network of independent scientists and research institutes located throughout the world.

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A Global Dialogue:

Natural Resources: The Sustainability Challenge

19–21 June 2000 at EXPO 2000, Hanover, Germany

SEI and a large team of international organisations has organised a Global Dialogue at Exop 2000 focusing on Natural resources. It will discuss challenges and opportunities at global, regional and local levels, operating on the principle that *natural resource security and human security* go hand in hand. The stakeholders – representing civil society, business, government and international organisations – recognise that they share both common interests and common responsibilities.

The Program

- three televised high-profile public awareness events with world leaders and film links on four continents
- three plenary workshop sessions: the global policy scene, vision for youth and summary session
- five parallel workshops: integrated ecosystem management; fresh water resources; forest resources; renewable energy; and markets, knowledge and sustainable development
- shared knowledge network sessions with concurrent World Engineers' Convention (www.vdi.de/wec)
- three full days of thematic display including award winning environmental films

The Participants

The Global Dialogue brings together experts, dignitaries and decision-makers from around the world. Participants include major leaders in business and government and key representatives from international development organisations and non-governmental organisations. **His Majesty King Carl XVI Gustaf** of Sweden will introduce and preside over the *Global Focus* Session on 19 June. A panel discussion entitled *Platform for the Future* will be held on 21 June.

Organisers

The Global Dialogue is organised by Stockholm Environment Institute (SEI) in co-operation with: Bellagio Forum for Sustainable Development, Deutsche Bundesstiftung Umwelt, Global Environment Facility, World Business Council for Sustainable Development, UNEP, KfW, Earth Council, Volvo, Carl Duisberg Gesellschft, WWF, GTZ, Leadership for Environment and Development, The International Herald Tribune, IMERCSA, WFW, Verein Deutscher Ingenieure, Deutsche Welle, Deutsche Bank AG, World Commission on Forests and Sustainable Development and Expo 2000.

For more information see the Global Dialogue website: http://www.sei.se/gd.html

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