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UNU-IAS Report

Renewable Energy Technologies in Developing Countries

Lessons from Mauritius, China and Brazil

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Cover photo: Reflection of Sky in Solar Array Panels, Phoenix, Arizona, USA; Mark Segal / GettyImages

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Foreword

The development paradigm in contemporary history underlines the role of technology in socio-economic advancement. Day-to-day life has been transformed by a broad range of technological products, enabling people to live longer and to enjoy a better quality of life. Technology has been the core element driving economic development in industrialized societies, whereas for many less-developed countries, technology seems a remote or unattainable goal.

Technology development and technology transfer have been the stated objectives in a number of international conventions and legal instruments, thus setting a legal framework for technology development, collaboration and transfer among countries. Innovative ideas for merging local capabilities with transferred knowledge and technology from other countries often produce workable solutions to many development needs. Such cases are often unique and highly contextual. Nevertheless, documenting and analyzing the underlying principles in each case might provide lessons which can help other developing countries in similar cases.

This report looks at three cases in which developing countries – Brazil, China and Mauritius -- have applied creative solutions to technology development and environmental protection in the field of renewable energy. It attempts to identify the common denominators that have contributed to their success.

The report is targeted at government policy-makers and actors involved in renewable energy technologies. It is hoped that the study will facilitate learning from success stories, and will encourage other developing countries to focus on their innovative capacities in addressing their technology needs.

A.H. Zakri
Director, UNU-IAS

Executive Summary

Renewable energies such as wind, biomass, solar, geothermal and hydro offer many well-documented benefits for developing countries, and represent an important component of any sustainable energy development program or national energy strategy. With the emergence of the flexible mechanisms under the Kyoto Protocol in recent years, the Clean Development Mechanism (CDM) has received heightened attention as an important catalyst to support renewable energy in developing countries. With the entry into force of Kyoto in 2005, considerable attention within the renewable energy community will likely be focused on the specific procedures required develop CDM-eligible investment projects.

While market-based polices such as the CDM can be instrumental in creating new renewable supply and overcoming the cost disadvantages of renewables, the successful deployment of new energy technologies needs to be understood among a wider range of catalytic factors. This report reviews three renewable energy developments that have taken place in developing countries without significant foreign investment or the CDM: bagasse cogeneration in Mauritius, ethanol in Brazil and solar hot water in China. In addition to policy interventions into the market, the case studies also point to the importance of factors such as industrial capacity and the geographic distribution of energy sources. Solar hot water in China, for example, was not enhanced with public subsidies or other market schemes, but emerged as a competitive solution for several other reasons. Notably, the proliferation of solar hot water systems in the country has closely mirrored the combined patterns of the geographic distribution of solar resources and constraints on regional natural gas supply.

The report concludes, based on the case studies, that renewable energy planning should be approached strategically by developing countries, with specific technological strategies grounded in national industrial capacity and energy resources. From the perspective of renewable energy development, the CDM and other international facilities for technology transfer related to carbon management, can be approached most effectively as agents for scaling up existing technological efforts and innovative adaptations in local energy sectors. While such mechanisms will garner important financial and technological resources for developing countries, successful projects and sustainable market development will surely include a strong awareness of conditions pertaining to the endowment of renewable energy resources, industrial capabilities and local socio-political attitudes and values.

Introduction

At present, the arguments in favor of expanded renewable energy around the globe and in developing countries are particularly convincing. As the 2005 Beijing International Renewable Energy Conference agreed: "The growing awareness of energy poverty in developing countries, the risk of climate change and the important role that renewable energy should play in sustainable development and energy security, the increasing number of international initiatives and commitments, and volatility of world energy markets, provide an unprecedented opportunity for addressing the strategic challenge of transforming our energy systems". [1]

The doubling of oil prices in recent years and the consolidation of evidence supporting the impacts of climate change have put alternative energy on the agenda of many political discussions. The recent Beijing conference and other related events such as the World Summit on Sustainable Development, the Bonn International Conference for Renewable Energies, the G-8 Gleneagles Summit, and the UN Framework Convention on Climate Change are key stages of a significant history of international discourse to promote renewable energy technologies globally. There is no shortage of approaches and principles that have been put forward as guidelines for successful deployment of renewables. The Beijing Declaration, for example, highlighted the need to create a supportive policy and institutional framework, to secure public sector commitment for research and development and procurement, to level the playing field with conventional sources, to promote private sector investment, to support national renewable energy industries and to provide greater access to finance.

This report looks at the context-specific factors behind the success of three renewable energy deployments in the developing world: bagasse electricity in Mauritius, ethanol in Brazil, and solar hot water in China. All three developments have taken place in relatively high-income developing countries and constitute significant market deployments on a global level. Brazil's ethanol market and China's solar hot water market are the largest in the world. The case studies are not presented as blueprints for success or as illustrations of appropriate or optimal technological choices. The intention, rather, is to understand better the underlying factors that contributed to each deployment in its own context, and to draw out the historical and local drivers that need to be understood and leveraged for effective renewable energy development, in conjunction with new finance mechanisms such as the CDM.

1 Beijing Declaration on Renewable Energy for Sustainable Development

Background

All energy sources originate from the sun (solar energy), the earth's crust (geothermal energy), the gravitation pull of the moon (tidal energy) or nuclear energy (Goldemberg, 2004). Other energy sources originating from the sun's radiation include hydropower, wind power, solar light and heat, and biomass. Fossil fuels such as coal, natural gas and oil, while considered non-renewable, originated from solar energy converted to organic material through photosynthesis hundreds of million of years ago.

Renewable energy technologies convert these energy sources into useful applications. For example, the absorption of sunlight by darkened surfaces or flat plate collectors can produce heat at sufficient temperatures to create electricity in solar thermal electric plants. Photovoltaic cells convert the ultraviolet component of sunlight into electricity. Wind turbines convert wind turbulence into electricity, and dams can be used to convert the kinetic energy of falling water into electricity. Geothermal energy is produced from hot water or vapor that can be used for heat or electricity generation. Biomass includes both traditional fuels like firewood and more advanced fuels (like ethanol and biodiesel) that are derived from crop residues, wastes and other organic materials. Ocean and tidal currents can also be exploited for electricity generation.

Global Status of Renewable Energy

According to the International Energy Agency, in 2002 about 80% of global primary energy consumption came from fossil fuels, about 6% came from nuclear and about 14% came from renewable resources, most of which was biomass, followed by hydropower (see Table 1). Most growth in renewables, despite the recent surge in new technologies like wind turbines and photovoltaics, took place between 1970 and 1990 when supply grew by 2.8% per year. Some mature technologies such as geothermal and hydropower declined during the 1990s. Currently, the fastest-growing markets are for wind and

photovoltaics, which have seen annual growth rates as high as 40%, mainly in Europe and Japan. In 2003, annual investment in renewable energy was estimated at $22 billion worldwide -- a significant amount considering that investments in conventional power generation typically average about $120-$160 billion per year (Martinot, 2004). Of the $22 billion invested in 2003, 38% went to wind, 24% went to solar photovoltaics, 21% went to solar hot water and 17% went to remaining technologies like geothermal, small hydro and biomass.

According to the International Energy Agency, 18% of world electricity demand was met by renewables in 2002. A few countries meet almost all of their electricity needs with renewables, (mostly from hydropower), including Brazil, Paraguay, Iceland, Nepal, Mozambique, the Democratic Republic of Congo, Uruguay and Norway. China makes significant use of small-scale hydro. The largest markets for non-hydro renewable electricity are in the United States, Japan and Germany, and the most significant growth is in Europe, particularly Denmark, Germany, Finland, Iceland, Spain and the Netherlands. In 2002, Denmark, Spain and Germany together produced 58% of the world's wind power. The United States is the largest producer of geothermal electricity in the world, at 15 TWh in 2002, followed by the Philippines with 10 TWh and Indonesia with 6 TWh. Biomass accounts for 1% - 3% of electricity in OECD countries, and in 2002 supplied around 21% of electricity in Mauritius, 14% in Finland, 3% in
Brazil and 3% in Austria.

In terms of non-power sectors, global biofuel consumption in transport was 8 Mtoe in 2002, representing 0.4% of total transport fuel consumption worldwide. Brazil's ethanol market accounts for around 70% of the world's total biofuel consumption. The second largest producer of ethanol is the United States, with around 23% of the global share, followed by Canada. The main biodiesel producing countries are France, Germany, and Italy, where the fuel is used mainly as a diesel blend, (5% or 20%). Austria, Belgium, Indonesia and Malaysia also use biodiesel. Worldwide, industry and buildings consumed about 1000 Mtoe of renewable energy in 2002, mostly from traditional biomass in developing countries. In Brazil, biomass accounted for 36% of industrial energy demand, in Africa 29% and in India 22%. Commercial solar hot water is also expanding, particularly in China, but also in Japan, the United States, Germany, Turkey and Israel.

Energy Source	Energy Use (Mtoe)	Share of Total Energy Demand
TCoal	2389	23%
Oil	3676	36%
Gas	2190	21%
Nuclear	692	6%
Renewables	1398	14%
Biomass (traditional)	*1119 (763)*	*11% (7%)*
Hydro	*224*	*2%*
Other renewables	*55*	*1%*
Total	10345	100%

Table 1 World Primary Energy Demand 2002 (IEA, 2004a)

Renewable Energy and Developing Countries

There are a number or reasons why renewable energy technologies are potentially important for developing countries. As with industrialized countries, renewable energy technologies can contribute to greater energy security and diversity, foreign exchange savings on fossil fuel imports, reduction of local air pollution and greenhouse gas emissions, as well as employment and industrial development. In developing countries, renewable technologies and off-grid sources of power like small hydro and mini-grids can also contribute to the provision of basic services such as electricity, pumped drinking water, and cooking fuel. While many of these services can and should be provided through a range of strategies, including improved fossil fuel technologies and efficiency gains, renewable technologies have an important role to play in the future energy supply of all countries. Investments in renewable technologies can be a strategy to meet multiple goals, including development and poverty reduction.

Energy demand is increasing, and is expected to continue to increase especially quickly in developing countries. In recent years, energy demand in developing countries has been growing, on average, three times faster than in OECD countries. As a result, total energy demand in developing countries is projected to exceed that of OECD countries in the coming decades. In addition, developing countries are increasingly shifting away from traditional biomass and relying more on fossil fuels to meet their growing energy needs. As indicated in Table 2, the IEA projects that biomass consumption will decline in relative terms, while energy use rises significantly and other renewables make only modest contributions in coming years.

Some of these trends can certainly be seen among growing economies in Asia. Already, China is the second largest consumer of primary energy in the world, and the largest consumer of coal. The IEA projects that between 2002 and 2030, China will account for 21% of world growth in primary energy demand, 53% of incremental coal demand and 19% of incremental oil demand. Per capita electricity consumption will almost triple by 2030, and Chinese vehicle ownership is expected to reach more than 90 per 1000 persons in 2030, or a total stock of over 130 million vehicles, (compared to 220 million in the United States today).

Increased investment in renewable sources can mitigate some of the impacts of these trends. Renewable energy can potentially increase domestic energy security and reduce expensive fossil fuel imports. [2] Energy imports tend to rise with economic growth. For example, the Asian region's oil import dependence is expected to double from 43% to 78% in 2030. By 2020, India's oil imports are expected to rise from 70% to 85% of consumption (see table 3). As international competition for energy resourc

	1971		2002		2030	
	OECD	Developing	*OECD*	Developing	*OECD*	Developing
Primary Energy Supply (Mtoe)	*3387*	1228	*5436*	3834	*6953*	7873
Hydro	*75 (2%)*	16 (1%)	*106 (2%)*	94 (2%)	*131 (2%)*	202 (3%)
Biomass/Waste	*83 (2%)*	580 (47%)	*181 (3%)*	922 (24%)	*359 (5%)*	1221 (16%)
Other RE	*4 (0%)*	0 (0%)	*33 (1%)*	21 (1%)	*159 (2%)*	89 (1%)

Table 2 Energy Demand and Renewables in OECD and Developing Countries (IEA, 2004a)

	2002	2010	2020	2030
OECD	63	68	79	85
Developing Asia	43	59	72	78
China	34	55	68	74
India	69	80	87	91
Other Asia	40	54	68	76

Table 3 Oil Import Dependence in Net Importing Regions (%) (IEA, 2004a)

2 Many developing countries subsidize domestic fossil fuel consumption, placing a heavy burden on national budgets and foreign exchange earnings. With higher world oil prices in recent years, many governments have increasingly subsidized fossil fuel imports. In 2004 Indonesia planned, for example, to spend 14 trillion rupiah (US$1.5 billion) on fuel subsidies but actually spent four times that amount (The Economist, 2004).

es increases, there is also pressure to look for more stable and secure energy sources for security reasons, suggesting an important role for domestic renewable supply in developing countries.

In addition, renewable energies can be part of larger efforts to promote wider access to energy. More than 2 billion people in developing countries do not have access to modern energy services, and 2.4 billion people rely on traditional biomass for their basic energy needs. Lack of access to energy limits access to information, education, economic opportunity, and healthier livelihoods, particularly for women and children. Building on lessons learnt with ethanol, Brazil's ProBiodiesel programme has developed measures to promote social inclusion, and promote more equitable ownership and development of the biodiesel market. Provisions include tax incentives for "family agriculture" as well as preferential treatment for harvests that earn "social fuel stamps" certifying the regional distribution of biodiesel crops. In addition, biodiesel is being deployed for power generation at the community level, as well as a transport fuel, in order to help the country meet its commitment for universal access to electricity by 2015.

Renewable energy can also help reduce local air pollution, which has generally been increasing in direct proportion to increased energy consumption in developing countries, particularly in the transport sector. According to the World Business Council for Sustainable Development (2004), conventional pollutants like NOx, CO, SOx and particulate matter (PM) will continue to rise over the next two decades in developing country cities. Two and three wheeled vehicles are expected to be significant contributors to rising PM levels in non OECD countries, and freight trucks will be major contributors to rising levels of NOx. While an integrated vehicle emissions reduction strategy is critical to reduce health impacts, increased use of renewable fuels like ethanol and biodiesel blends could contribute to reduced local air pollution from transport. Similarly, coal-fired plants that contribute to a number of local air pollutants including SOx, NOx and acid rain also pose serious health and environmental problems.

Renewable energy can also help reduce greenhouse gas emissions. Developing countries are expected to contribute to the majority of growth in greenhouse gas emissions in coming decades. According to the IEA, developing countries will be responsible for 70% of the increase in CO_2 emissions to 2030, and their total emissions will overtake those from OECD countries in the early 2020's. Although developing countries currently have no emission reduction commitments under the Kyoto Protocol of the United Nations Convention on Climate Change, there is increasing international pressure to involve developing countries further in efforts to mitigate climate change after the 2008-2012 commitment period. Moreover, developing countries stand to benefit through Kyoto's flexible mechanisms by attracting investment in climate-friendly technologies from industrialized countries.

Investment in renewable energy technologies can also potentially lead to industrial development, job creation and increased exports for developing countries. There are particular opportunities for developing countries to exploit advantages in biomass resources. A number of developing countries are investing in increased bio-fuel production, including China, India, Brazil and South Africa. The often-cited success story of the Brazilian ethanol industry (discussed below) demonstrates the potential gains in industrial development, exports and employment in the alternative fuels sector. The programme has led to the creation of an estimated 720,000 jobs.

Finally, since the bulk of energy infrastructure investments are expected to take place in developing countries over the next decades, there is a certain urgency to help ensure a larger portion is diverted toward renewable energy infrastructure in that timeframe, thus establishing the basis for future investments. Experience in industrialized countries shows that once basic infrastructures and energy-intensive industrial capacity are in place, investments tends to shift from new capacity toward replacements. Although new technologies can still be added, they tend to occur at much slower rates and with less ease than replacement investments, highlighting the importance of initiating renewable energy technology pathways sooner rather than later.

There have been a number of attempts over the past decades to encourage the transfer of renewable energy to developing countries. In the 1970s and 1980s, many development agencies promoted small-scale technologies like biogas cooking stoves and solar heaters and faced sustainability and replication problems. In addition to higher costs of those technologies compared to conventional systems, the transfer of renewables to developing countries has also faced other barriers such as political instability, corruption, lack of institutional support, lack of planning for energy or land use, low technical capacity of domestic firms, and other challenges associated with technology transfer (Wilkins, 2002).

With the 1992 Rio Earth Summit, a new effort was launched in the context of climate change. The Global Environment Facility (through UNEP, UNDP and the World Bank) became a principal financing mechanism for a number of international environmental agreements, including the climate change convention. Since 1990, the GEF has provided approximately $1 billion in energy and energy efficiency financing, and the World Bank Group [3] since 1990 has invested about US$700 million in renewable energy projects. In 2005, the group committed to scale up its lending for renewable energy 20% annually

3 The World Bank Group has a number of activities related to renewable energy such as the Renewable Energy and Energy Efficiency Fund, the Energy Sector Management Assistance Programme (ESMAP), Asia Alternative Energy Programme (ASTAE), the Solar Development Group, the Photovoltaic Market Transformation Initiative and carbon funds such as the Prototype Carbon Fund and the Community Development Carbon Fund.

over next 5 years. Along with financing, these institutions also provide capacity-building and information services. In the late 1990s, a number of international corporations like BP and Shell began financing renewable energy projects in developing countries. National-level market policies in industrialized countries are also often seen as important for helping reduce overall costs through growth in economies of scale, and making the technology more affordable for developing countries. The *G8 Renewable Energy Task Force* in 2001, for example, urged the implementation of national plans in developed countries in order to drive down costs to underpin the development of markets in developing countries.

International Policy Background

At present there is no overarching international agreement or framework that deals primarily with the proliferation or transfer of renewable energy technologies .[4] However, renewable energy has played a growing role in global environmental summitry over the past three decades, and particularly since the issue of climate change entered the international environmental agenda. In the first global summit on environmental issues at Stockholm in 1972, there was little mention of energy. The Stockholm Action Plan on the Human Environment made only minor references to energy (in recommendation 57-59), highlighting the environmental effects of energy use, the need for information exchange and further study. One of the principles of the conference declaration (principle 5) calls for the protection of "non-renewable resources", but the conference documentation does not reference renewable energy technologies in any significant manner.

Following the oil shocks of 1973-4 and 1980-81 and the emergence of ozone depletion and climate change as major policy issues, the energy sector was given greater attention at the United Nations Conference on Environment and Development in Rio in 1992. Agenda 21's Chapter 9 on Protection of the Atmosphere dealt most explicitly with energy issues. Sections 12 and 18 call for the development of cleaner sources of energy, for example. The Rio Summit [5] also coincided with the creation of the United Nations Framework Convention on Climate Change (UNFCCC), which remains the main international agreement with implications for energy and renewable energy technologies.

There are a number of references to technology transfer throughout the UNFCCC. Article 4.1(c) of the UNFCCC commits parties to *promote and cooperate in the development, application, and diffusion, including technology transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases, and Article 4.5 asks developed countries in particular to take all practical steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other parties, particularly developing country parties, to enable them to implement the provisions of the convention.*

Of the major international environmental summits, the 2002 *World Summit on Sustainable Development* in Johannesburg dealt most directly with renewables and with energy in general. While the conference fell short of sought-after timetables and targets for development of renewable energy, the intense debate on the issue gave rise to strong language in the conference documentation. Article 19 of the Johannesburg Plan of Implementation, calls on the international community to:

> *diversify energy supply by developing advanced, cleaner, more efficient, affordable, and cost-effective technologies including fossil fuel technologies and renewable technologies, hydro included, and their transfer to developing countries on concessional terms as mutually agreed;. With a sense of urgency, substantially increase the global share of renewable energy sources with the objective of increasing their contribution to total energy supply, recognizing the role of national and voluntary regional targets as well as initiatives, where they exist, and ensuring that energy polices are supportive to developing country efforts to eradicate poverty, and regularly evaluate available data to review process to this end.*

In 2004, the German government hosted the *International Conference for Renewable Energies* in Bonn, which adopted an action programme and political declaration that re-iterated much of the discussion from the WSSD. The 2004 Bonn Declaration highlighted both the importance of driving down the costs of renewables in developed countries, and the role of indigenous technological development in developing countries, calling for:

> *additional targeted research and development, especially by developed countries, including indigenous research and technology development in developing countries and economies in transition. Emphasis should be on affordability and cost reduction, on innovative business and financing models and on cost-effective, consumer friendly cost recovery models, recognizing that different renewable technologies offer different opportunities and face different constraints.*

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4 There have been some attempts to create an 'International Renewable Energy Agency' to promote technology transfer, based on the International Atomic Energy Agency model. See World Council for Renewable Energy.

5 Five years after UNCED, the UN General Assembly held a review of Agenda 21, and called for the 9th session of the Commission on Sustainable Development (CSD) to address energy issues. In 2001 CSD-9 established a consensus over the lack of energy service in developing countries, the disparity in energy consumption around the world, the unsustainable pattern of energy consumption and facilitated the publication of the World Energy Assessment.

Similarly, the 2005 Beijing International Renewable Energy Conference emphasized further promotion of the energy agenda set by the Johannesburg Plan of Implementation, recognizing the "unprecedented opportunity for addressing the strategic challenge of transforming our energy systems and closing the energy divide between poor and rich, and between developing and developed countries". The conference asked the next round of the UN Commission on Sustainable Development to. [6]

> *consider an effective arrangement to review and assess progress towards substantially increasing the global share of renewable energy as foreseen in paragraph 20(e) of Johannesburg's Plan of Implementation. This would provide a long-term prospective and encourage prompt action. Such periodic review could offer opportunities for enhanced national, regional, and international co-operation on renewable energy for sustainable development through, for example, exchange of lessons learned and best practice and a more favorable environment for technology transfer and the rapid commercialization of innovative renewable energy technologies. The review could also be useful in addressing the linkages between energy and the commission's biannual thematic cluster, and voluntary reporting could be enhanced through inputs from relevant international organizations and networks.*

The Clean Development Mechanism

The Clean Development Mechanism (CDM) of the UNFCCC Kyoto Protocol offers the most promising international regulatory framework for the transfer of renewable technology from North to South, and represents the first global incentive-based regulatory system to address an environmental externality. Under the CDM, one of the three main flexible mechanisms of the protocol (in addition to Joint Implementation and Emissions Trading), developed countries (Annex 1 parties) with emission reduction obligations can earn credits or CERs (Certified Emission Reductions) by investing in emission reduction projects in developing countries, taking advantage of lower marginal abatement costs. Developing countries (non-Annex 1 parties), in turn, benefit from investment flows toward sustainable development and contribute to the general goals of the convention. While reductions in GHGs from projects will be closely measured with international rules and standards, the identification of sustainable development criteria for CDM projects has been left to the discretion of individual host countries.

The 2001 Marrakech Accord under the UNFCCC included guidelines for implementing the CDM. Participants must have ratified the Kyoto Protocol and established a National CDM authority. Projects must be voluntary among the parties [7], and have real and measurable emissions reductions that need to be demonstrably "additional", i.e. the reductions would not have occurred in the business as usual (baseline) scenario. Also, project screening has tended to require that a project: is not duplicating a common practice, is less economically attractive, exceeds legal or policy requirements, uses more advanced technology than normal practice in the country, and cannot normally be implemented (Riso, 2005). The CDM project cycle includes: project design, registration, monitoring, verification and issuance of CERs. Projects are approved by the CDM Executive Board, which operates under the authority of the Conference of the Parties to the UNFCCC.

The CDM is in its beginning stage and its role in reducing emissions or promoting renewable energies in developing countries is not yet known, although it is generally agreed that the mechanism could transfer billions of dollars towards cleaner technologies to developing countries. It is important to note that the thrust of the climate regime and the CDM is to reduce emissions of the six greenhouse gases covered by the Kyoto Protocol, and not to promote renewable energy *per se*. Under the CDM, renewable energy will compete with other options such as switching to fossil fuel options with lower carbon emissions, re-forestation and afforestation, methane gas capture, energy efficiency and so forth.

At the same time, host countries can and have included provisions for the promotion of renewable energies within their criteria for defining sustainable CDM projects (Huq and Reid, 2005). Although the CDM has essentially been operative since the adoption of the Marrakech Accords, the market is really only just emerging. However, the CDM portfolio is growing rapidly and has the capacity rapidly to outpace traditional multilateral lending programs, or even foreign direct investment in energy. Over the past two years the CDM has attracted between $US 3-4 billion and the current portfolio of CDM projects indicates a substantial role for renewable energy. [8]

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6 The UN Commission for Sustainable Development 14/15 in 2006/2007 plans to deal with climate, energy and transport. Energy was also major theme of the ninth session of the Commission on Sustainable Development (CSD-9), held in 2001. Countries agreed at CSD-9 to emphasize the development, implementation, and transfer of cleaner, more efficient technologies.

7 CDM projects can be initiated by developing countries themselves, in which case they are called unilateral CDM projects.

8 As of end of 2005 there were 513 CDM projects under review. In terms of renewable energy projects there were 55 wind, 83 hydro, 3 solar, 119 biomass (including incineration), and 21 biogas. While at the end of the 2005 nearly half of the proposed projects were in the electricity sector, the majority of credits are expected to come from industrial gas reduction projects such as methane capture (Fenhann, 2005).

Factors Influencing Markets for Renewable Energy

Although the development and transfer of renewable energy technologies to developing countries face many challenges, a review of the status of renewable energy around the world shows that some of the greatest successes in this sector are taking place in developing countries themselves. The rest of this report compares experiences with different renewable energy developments in Brazil, China and Mauritius in order to understand better how successful markets have evolved in the developing country context.

While public policy at the national level is often cast as the central element in promoting new markets, a wider perspective is used here in order to highlight other supportive local conditions surrounding the development of the industry and market. A comparison of the recent evolution of wind energy markets in different European countries (Reiche and Bechberger, 2004) suggests that the role of government policy, while important, needs to be understood in a broader framework of factors including: geography and energy starting position; economic environment and relative energy prices; politics, technological development; and 'cognitive environments'. Here, we suggest four broad and overlapping categories in a similar fashion:

- Geography and energy resources
- Industrial capacity and innovation
- Policy
- Socio-political attitudes and values

Geography and Energy Resources

Renewable energy technologies typically require local access to renewable energy sources. The natural endowment of renewable sources varies widely around the world, as do endowments for conventional resources, although access to renewable resources is certainly more widespread. The local endowment of particular resources is a critical factor in determining which resources should or do get developed, primarily because renewable resources such as wind, solar, geothermal and hydro cannot be imported like coal, oil and gas (although energy carriers like electricity or potentially hydrogen can be transmitted over long distances), and certain forms of biomass may be uneconomical to transport at a large scale. Also, the potential of renewable resources is largely determined by local geographical conditions such as the nature of wind turbulence in specific regions, or the location of suitable for hydro-electric development and so forth.

Natural flows for renewable resources are immense and virtually limitless. The volume of natural solar energy, for example, far exceeds fossil fuel reserves. While complex to measure, there are some regional comparisons. According to the World Energy Assessment 2000, the greatest potential for hydroelectric development is believed to be in Centrally Planned Asia (as classified by the Assessment), followed by Sub Saharan Africa and Latin America and the Caribbean. The Middle East and North Africa have the greatest solar energy resources, followed by Sub-Saharan Africa and Russia. North America has the largest estimated wind energy resources, followed by the former Soviet Union and Pacific Asia. Biomass resources are generally abundant in most parts of the world, but often lack significant commercial development and energy conversion applications.

In addition, the non-availability of affordable fossil fuels resources is also a key trigger for the development of renewable energies due to the potential cost savings and other benefits that would flow from investments in local renewable energy supplies. Fossil reserves of oil and gas are concentrated in a few key areas. Most proven recoverable reserves of oil are in the Middle East/North Africa, followed by Latin America and the Caribbean, and the former Soviet Union. Most reserves for natural gas are located in the former Soviet Union, followed by the Middle East/North Africa and Latin America and the Caribbean. North America possesses the greatest coal reserves, followed the former Soviet Union, China and Australia. Most exploitable uranium resources are in the former Soviet Union, followed by Pacific OECD, North America and Sub-Saharan Africa.

Industrial Capacity and History of Innovation

Renewable energy development typically relies on related business and industrial capacity to deploy new renewable technologies, including aspects related to financing, labor, materials, scientific knowledge, manufacturing capacity, marketing, research and development and so forth. With the exception of hydro power (and increasingly wind), industrial production and business models are largely underdeveloped for renewables around the world. As such, renewables tend to evolve from niche markets and adaptations from established industries in select countries. Biofuel transport programmes, for example, typically re-direct existing industrial ethanol or agricultural production to the transport sector. Biodiesel programs in Europe build upon local agricultural industries, and ethanol gasoline additive programmes in South Africa and India have sourced ethanol primarily from existing industrial and pharmaceutical applications.

Renewables also tend to emerge as robust markets on the basis of longstanding experience in the industry or in a related industry. The Danish wind industry, for example, which is largest in the world in terms of the proportion of domestic energy supply, rests on a long tradition of innovation and technological development related to the wind turbine sector, dating back to beginning of the twentieth century. By 1918, wind power was in fact already contributing 3% of Denmark's electricity needs, with 120 rural power stations, a level much higher than most industrialized countries today (Meyer, 2003).

Also, renewable technology deployments typically rely on new and successful forms of integration with existing infrastructure so that systems can function effectively in terms of technology and markets, and overcome intermittency and market uncertainty problems related to renewables. Such forms of integration include measures to ensure compatibility with fueling equipment, distribution systems, vehicles, electricity grids, appliances and so forth, as well as ensuring the availability of backups and alternative fossil fuel systems. They also often require new commercial arrangements and forms of risk-taking.

Policy

Renewables typically rely heavily on public support in different ways. Government policy helps overcome barriers like higher initial capital costs, failure to incorporate fuel price risks or environmental externalities in decision-making, and higher transaction costs. New policies can also help reduce regulatory barriers like lack of legal frameworks for independent power producers, restrictions on siting and construction, transmission access, utility interconnection requirements, and liability insurance requirements as well as market performance barriers such as lack of access to credit, perceived technology performance risk and lack of commercial skills and information (Beck and Martinot, 2004). In most cases, governments supply research and development support for successful domestic applications through grants, coordination and target-setting. The Japanese photovoltaics market, for example (which accounted for almost half of global installations in 2001), has received concerted government research and development support from the Japanese government since the 1970s.

Examples of market policies include guaranteed prices for suppliers, as in Germany's grid feed-in laws for wind, or investment and production tax credits, as practiced in the United States, or direct subsidies to consumers as in Japan's photovoltaic programme. A number of countries including the UK and Australia, and many US states, have recently created new markets for renewable electricity by setting sector quotas that must be achieved by market actors (typically electricity retailers) or bought from competitors through a trading system. Other indirect market mechanisms such as reduced subsidies or increased sulfur or carbon taxes on fossil fuels, or emissions trading schemes like the European Emissions Trading scheme or others than allow for offset projects like CDM projects, can also encourage renewable energy investments. For developing countries, there are typically soft loans and other forms of support available from international financial institutions like the World Bank or the Indian Renewable Development Agency. Renewables also require additional policy support such as overall coordination and direction of technology deployment programs, codes and standards development and public awareness-raising measures.

Socio-Political Attitudes and Values

Renewable energy deployments typically require attitudes in society (among politicians, industry and citizens) that support the new technologies. Such values, for example, could include: preferences for distributed energy technologies or community owned energy supplies; an aversion to nuclear power or foreign energy dependence; a belief in the environmental or health benefits of renewable energies; or confidence in the potential financial savings from reduced fossil fuel imports. Many decisions by governments to promote renewables are, in part, supported by the purported virtues of renewables as low-emission, safe energy sources that reduce reliance on energy imports from political trouble spots, and promote sustainable development. Decisions to support renewable technologies in Europe, for example, have been supported by strong political and public sentiments that favor climate-friendly and non-nuclear, while investments in the US and Japan are strongly supported by reducing dependence on foreign energy imports. It is worth noting that opposition to renewable energy is also highly influenced by values and perceptions as demonstrated by concerns over visual impact of wind farms in the UK. The degree to which certain values and attitudes emerge as fungible support for pro-renewable policy depends on the political climate and attitudes of existing political parties, the impact of supporting science, and the nature of political decision-making.

Bagasse Cogeneration in Mauritius

The island of Mauritius is located 20 degrees south of the equator in the Indian Ocean. It has a total land area of 1,865 km2 and a population of 1.2 million. The GDP per capita was $US 4,352 in 2003. There are no reserves of oil, gas or coal, and it depends heavily on imported fuel resources. Demand for electricity has significantly outpaced growth in the national economy in recent years. From 1976-2002 electricity sales grew by 625%, while GDP grew by 275%. In 2004 1,923 GWh were generated, of which 62% came from fossil fuels, 17% from hydro and 21% from sugarcane bagasse. [9]

Technology and Market Development

Bagasse is a major energy source in Mauritius. The sugarcane crop occupies around 85% of the arable land, and annual cane production in a year from cyclones or drought amounts to around 5.5 million tonnes. [10] Interest in the use of bagasse for electricity generation started in Mauritius in 1957, when one sugar factory exported 0.28 GWh of electricity to the national grid. The price per kWh was low, but attractive enough to encourage other sugar factories to begin selling electricity in a similar fashion. By 1980, 14 out of the 21 factories on the island were exporting an annual total of around 27 GWh of such electricity to the grid. In many of these instances, the electricity was not modulated to the needs of the utility, and was intermittent in nature.

From the 1980s, sugar factories began to implement improved systems of cogeneration involving investment in boilers and turbo-alternators operating on steam pressures of 25-31 bars, coupled with investment in energy conservation in juice heating, evaporation and sugar boiling. In 1980, one factory invested in a 10 MW plant, of which 6 MW was supplied to the grid through a so-called "continuous power" purchase agreement (CPPA). The power agreement was matched with the cane processing capacity, bagasse availability and energy processing requirements. This investment increased total bagasse electricity export to the grid from sugar refineries to 43 GWh in 1982.

Bagasse power plants are now being built as separate entities, distinct from cane milling activity. One recently-built plant (2x35 MW) is located next to the sugar mill which supplies all the required bagasse (at an agreed moisture content) and condensed water in exchange for process steam and electricity from the plant. The steam pressure and temperature are 82 bars and 525°C respectively, and the plant is exporting around 125 KWh of electricity/tonne of cane to the grid. It burns the totality of the bagasse from the sugar factory and coal as a complementary fuel when bagasse is not available during the off-season. In 2004, 366 GWh (106 from bagasse and 260 from coal) were exported to the grid from this plant. The total electricity exported from the power plants located at sugar factories amounted to 725 GWh (318 from bagasse and 407 from coal) or 38% of the total generated in Mauritius in 2004.

The long period of bagasse energy development, starting from intermittent power and progressing to continuous export, has enabled the sugar producers to acquire skills, improve efficiency, and assume the operative capacity as energy utilities, rather than simply as cane processors. Throughout the development of cogeneration in Mauritius, the average amount of electricity exported per volume of cane has been constantly increasing – from 4 kWh/tonne of cane in 1971, to 12 in 1991, 35 in 1998 and 60 in 2004. If all the power plants reach an efficiency level commensurate with 82 bars operating pressure, a 120 kWh/tonne limit is considered achievable for the country. Mauritius has recently embarked on upgrading cane milling capacity with concurrent investment in energy plants. A Power Purchase Agreement for a new plant with 2x41.5 MW installed capacity was signed in February 2005, and is scheduled to be operational in mid-2007. The total anticipated annual electricity export is around 400 GWh, of which 135 GWh will be from bagasse. The remaining sugar and power plants are also scheduled to be upgraded, and the target of 120 kWh/tonne or 650 GWh (double the current amount) from bagasse obtained from 5.4 million tonnes of cane is considered achievable within the next 10 years.

Supportive Policies

A series of policy initiatives has helped to promote bagasse electricity in Mauritius. In 1985, a *Sugar Sector Action Plan* was developed to address issues of energy conservation and efficiency in sugar factory unit operations, bagasse storage and use for year-round generation, and the setting up of bagasse energy companies separate from sugar companies. The1988 *Sugar Industry Efficiency Act* contained a wide-ranging package of incentives and measures to promote bagasse energy. The Act made provisions for performance-linked rebates on electricity export duties payable by millers, income tax exemptions on bagasse sales and bagasse-generated electricity sales, increased allowances for equipment used for electricity generation, and other pricing measures.

9 Sugar cane at harvest contains sucrose, fibre and water as the most significant constituents. It is normally harvested free of extraneous matter (ie leaves) and delivered to sugar cane factories where the cane is unloaded, shredded and pressed in mills to extract the juice from which sugar is recovered. The fibrous fraction leaves the mills in the form of bagasse which has around 50% fibre, 48% moisture and 1-2% sugar (which is not recoverable economically). The bagasse has a calorific value of around 8,000 KJ/Kg and is burnt to meet the energy (steam and electricity) requirements for processing of cane into sugar and its by-products. This process in which electricity and heat (in the form of steam) are generated simultaneously in a single power plant (steam boiler coupled with turbo alternator) is known as cogeneration. In a sugar factory with a well-balanced energy system, the electricity generated out of the bagasse is in excess of the requirement for cane processing, and this excess can potentially be "exported" to the grid.

In 1991, the government (in light of the success of previous programmes and prompted by the oil spikes during the Gulf War) set up a high-powered committee with the assistance of the World Bank to devise a strategy to maximize electricity export from bagasse. The committee produced a *Bagasse Energy Development Programme* for the sugar industry, in consultation with various stakeholders. The objectives of the programme were to displace investments in fossil-based resources planned by the utility (normally met with public funds), reduce reliance on petroleum products, allow for the modernization and rehabilitation of the sugar industry and improve its viability, save on foreign exchange linked to fossil fuel imports, and contribute to the mitigation of greenhouse gas emissions. A World Bank loan (US$15 million) and a Global Environment Facility Grant (US$3.3) were secured for these goals.

Benefits

Exploitation of bagasse for electricity, in addition to providing a cheap source of electricity, is also associated with a number of other benefits. Bagasse electricity (along with hydro) has enabled significant savings in foreign exchange in Mauritius. Power plants have provided job opportunities during design and construction phases (lasting for 2-3 years) and for operation and maintenance over the lives of the plants. While bagasse burning does produce local emissions, particulate matter has been kept within permissible limits through after-treatment technologies, and lowering the number of sources through centralization of cane processing activities. In terms of carbon emissions, the 300 GWh of electricity sold to the grid from bagasse avoids the use of around 200,000 tonnes of coal annually. When one includes the energy used in cane processing, the total figure for avoided coal burning comes to 440,000 tonnes. Furthermore, a cane biomass yield of 120 t/ha is equivalent to a carbon sequestration of 18 t of carbon or 66 t of CO_2.

Ethanol in Brazil

Brazil is the largest country in South America, with a population of 181 million and a per capita GDP of $US3200. Brazil is Latin America's largest energy consumer, accounting for 36% of the region's consumption in 2000, and 35% of the CO_2 emissions. Since the 1970s, the Brazilian ethanol program has succeeded in demonstrating the feasibility of large-scale production of ethanol as a transport fuel. While the primary energy mix is dominated by oil (63%) and hydropower (19%), ethanol from sugarcane occupies an unusually high proportion of transport fuel --13% in 2002 (global biofuel consumption in transport was only 0.4% for that year). The path of the program, including its peaks and valleys over the past 30 years, has been primarily driven by world oil prices and the government's need to reduce expensive energy imports.

Proalcool Programme

The Brazilian government launched the Proalcool Program in 1975 after the first oil crisis and during a time of low world sugar prices. Initially the program managed to introduce 20% to 25% ethanol-blended gasoline in the country without requiring substantial engine modifications in vehicles. After the second oil crisis (1978/79), the program was expanded to include the use of hydrated ethanol (typically 96% ethanol and 4% water), which required the Brazilian auto industry to make technical changes to vehicles. By 1984, the number of cars running on pure hydrated alcohol reached 17% of the country's car fleet, and by the late 1980s neat alcohol was used in over one-quarter of the vehicle fleet (or 3-4 million vehicles, consuming nearly 10 billion liters per year). The remaining vehicles used blends of 22%-26% ethanol.

In the late 1980s, low oil prices made ethanol less cost-effective. Production slowed and the government cut soft loans for new distilleries, leading to a drop in demand for ethanol vehicles. As a result, the share of neat-ethanol vehicles fell from almost 100% of new car sales in 1988 to less than 1% by the mid-1990s. In 2000, however, the cost-effectiveness of ethanol as a substitute for gasoline was re-established, and in 2002 the Brazilian government re-engaged supportive policies. Taxes were reduced for manufacturers of ethanol cars, and credits were introduced for the sugar industry to cover storage costs to guarantee ethanol supplies. The government required industry to maintain a maximum ethanol price (60% of the gasoline price) and has begun to encourage ethanol exports in order to help stabilize demand. In 2006 the ethanol price has rose significantly above the agreed level, leading to a drop in consumption.

In 2002 Brazilian ethanol-powered cars re-emerged, comprising 32% of new car production in that year, and a further 5.5 billion liters of ethanol was used in gasoline blends. In 2003 the car industry introduced "flex-fuel" cars, allowing for ethanol or gasoline in any proportion, and in 2004 the production of flex-fuel cars increased from 48,178 in 2003 to 328,374, equaling 26% of demand for new automobiles. In 2004, Brazilian ethanol production reached 15.3 billion liters, with exports accounting for 2.3 billion liters. Recently, the country has begun ethanol investment projects in other parts of Latin America and Africa.

Policy and Technological Development

Market-based policy support has been a major driver of the Proalcool program.

In the first phase of the program, during the 1970s, public financing reached up to 90% of the investment required to build new distilleries, and up to 100% of the investment needed to expand sugarcane-cultivated areas for ethanol production. Provisions included negative interest rates, three-year grace periods and twelve-year payback periods. Also, the government established minimum ethanol prices, which were attractive relative to sugar prices, and softer taxation allowed for ethanol prices at the pump to remain attractive. These policies, along with fur-

Ethanol Distillery Process	Circa 1975	2004
Crushing capacity (tons of cane/day)	5500	13000
Fermentation time (h)	24	4 to 6
Beer alcohol content (OGL)	7.5	10.0
Extraction yield (% sugar)	93	97
Fermentation yield (%)	80	91
Distillation yield (%)	98	99.5
Total yield (liter hydr. alc./ton cane)	66	86
Total steam consumption (kg/ton cane)	600	380
Steam consumption - hydrated (kg/liter)	3.4	2.0
Steam consumption - anhydrous (kg/liter)	4.5	2.8
Boiler – Efficiency (% PCI)	66	87
Pressure (bar) / Temperature (°C)	21 / 300	85 / 530
Surplus bagasse (%)	Up to 8	Up to 78
Biomethane from stillage (Nm3/liter alc)	-	0.1
Stillage production (l stillage/l alcohol)	13	0.8

Table 4 Productivity Gains during Brazilian Ethanol Programme -1975—2004

ther pricing support and incentives in recent years, have made a significant contribution to encouraging industrial innovation and lowering ethanol production costs in Brazil. Table 3 refers to the productivity gains in different manufacturing capacities of the country's leading ethanol distillery equipment manufacturer (commanding approximately 80% of the market share).

Benefits

There have been a number of benefits to Brazilian society associated with the ethanol program, including foreign exchange savings of $18 billion (in 1990 US$) from 1978 to 1990 (Navarro, 1992). Social impacts include the creation of 720,000 direct jobs and 200,000 indirect jobs in rural areas - a significant outcome in Brazil, where rapid urbanization has led to considerable social and environmental problems. In terms of the environment, ethanol use has produced lower tailpipe emissions from vehicles, reducing health and environmental impacts and, accounting only for the replacement of gasoline, ethanol use reduced greenhouse gas emissions of 5.86 MtC per year from 1980 to 1990 (Macedo, 1997). At the same time, there have also been some negative impacts, related to deforestation to make way for cane plantations and questions concerning the benefits the program has accrued to local communities and workers.

Solar Hot Water in China

China is the world's most populous country, the second largest consumer of primary energy after the United States, and the third largest energy producer after the United States and Russia. Chinese energy demand has been increasing, and is expected to grow by approximately 5.5% per year to 2020, and to account for 20% of world demand by 2030. While China has traditionally relied heavily on coal to power economic development, the country is gradually increasing its use of oil, natural gas and coal-bed methane, as well as encouraging greater efficiency and use of renewables. Recently, China has emerged as the largest solar hot water user in the world, with 54% of the global market.

Market Development

The domestic market for solar hot water systems has grown rapidly in recent years, alongside China's economic growth. In 2002, China accounted for 40 million m^2 of the 73 million m^2 of installed solar capacity worldwide, installing 79% of all new solar collectors in that year. By the end of 2003, the accumulated installed solar collector area in China was 52 million m^2. The domestic industry (primarily small and medium-sized, privately-owned enterprises) has grown by about 27% per year in the last five years, expanding from some 1000 enterprises in 1999 to around 3000 enterprises by the end of 2002. In 2002, about 200,000 people worked in the industry (Hu and Li, 2002).

The growth in the solar hot water market in China has taken place in response to new demand from Chinese households, increased incomes and growth in construction. Prices for the solar systems have remained relatively low due to high competition, high demand and efficient manufacturing. All materials needed for the systems are locally available at low prices. As a result, Chinese solar water heaters are the most competitively priced in the world. In 2002, 70% of heaters were sold at prices less than RMB 1500 (US$180). Most of the systems in this price range were sold in the warmer climate regions, such as Jiangsu, Zhejiang and Yunnan. A further 26% of systems were sold between RMB 2200–3000 (US$270–360), suitable for colder climates.

Importantly, solar hot water systems avoid the fuel costs of alternative water heating systems. Natural gas or electric heaters, while not necessarily expensive in China (approximately 2000 RMB for a 3-4 person household), have significant fuel costs, and in the case of natural gas, face restrictions on fuel availability outside of Beijing, Tianjin, Shanghai and other cities with local gas production. The distribution of solar hot water is closely related to the geographic distribution of solar resources in the country, along with incomes and the cost of conventional fuels. In Kunming, for example, where electricity prices are high, solar hot water is used in 40% of the households.

Government Coordination

Solar hot water systems were recognized by the Chinese government in the *Fifth and Sixth Five-Year Plans* in the 1970s, and have been promoted in several policy and research programmes since. In the 1980s, flat plate collectors and combined storage water heaters were gradually introduced in rural areas, then expanded to urban areas in the 1990's. The *New and Renewable Energy Development Program in China 1996- 2010* and the *Development of New and Renewable Energy Industry Program 1999 - 2015* set a strategic direction for research and development, and national targets for solar energy. In the *Tenth Five Year Plan of New and Sustainable Energy Sector Development*, the government set a national target for the cumulative solar collector installation area of 64 million m^2 in 2005, and long term targets of 129 million m^2 and 232 million m^2 in 2010 and 2015 respectively.

Solar water heater distribution in China (2002)

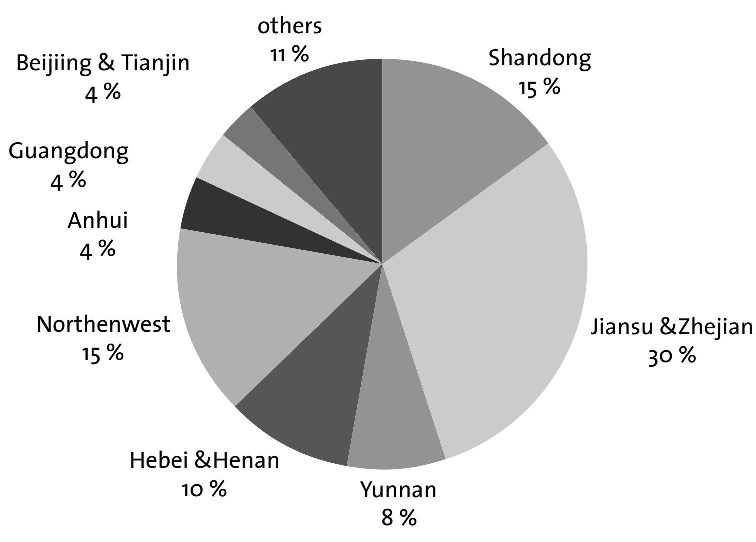

Figure 1 Solar water heater distribution in China, 2002 (NRDC, 2003)

The Chinese government has also coordinated international technical assistance programs, targeted at improved quality, durability and reliability. Three national test centers for solar thermal heaters have been established in Beijing, Wuhan and Kunming, through the *Accelerating China Renewable Energy Commercialization Program*, run by the Chinese Government with the United Nations Development Program and Global Environmental Facility (UNDP/GEF). A national certification center has been also been set up in Beijing under the UNDP/GEF program.

Recently, the Chinese government, together with the United Nations Fund for International Partnerships (UNFIP), has developed a guidebook and model for integrating solar water heaters into buildings, including a set of technology standards and building codes, under the *Improvement and Expansion of Solar Water Heating Technology in China* program. With growing interest in aesthetic, building-integrated solar water heaters, 100,000 m^2 floor-area of demonstration buildings has been constructed in Beijing, Shanghai, Yunnan, Anhui, Shandong and Tianjin under the UNFIP program in the last two years. These projects have shown how solar heater manufacturers, city planners, real estate developers, architects and builders can cooperate effectively in the integration of solar water heaters into buildings. As a result, industry has begun working directly with a range of these groups to develop large-scale projects for collective solar water heating systems for high-rise buildings and new residential districts, instead of selling directly to individual households for existing buildings. At present, these large projects account for about 20% of the market, a share which is growing.

Discussion and Conclusions

The development of the bagasse electricity market in Mauritius, ethanol market in Brazil and solar hot water market in China demonstrate successful renewable energy deployments in diverse emerging economies. The Chinese hot water market and Brazilian ethanol market are, in fact, the largest markets for those technologies in the world, and the proportion of bagasse-generated electricity in Mauritius is one of the highest in the world. As such, these cases demonstrate how developing countries can expand renewable energy supply while achieving industrial and economic growth. How did these market developments occur?

Geography and Energy Resources

Abundant sugarcane crops and few fossil fuel resources help to explain the origins of the success of ethanol in Brazil and bagasse cogeneration in Mauritius. In both Brazil and Mauritius, sugarcane is a predominant national resource and has been harvested for hundreds of years. In Mauritius, sugarcane has become the dominant crop under prevailing agro-climatic conditions and occupies 85% of the land area. Both countries also face potentially high-cost fossil fuel imports, providing biomass fuels with a price advantage, especially during periods of high world oil prices. In Brazil in the early 1970s, late 1970s and early 2000s, high-priced energy imports played a catalytic role promoting ethanol. In addition, sugar crop yields, relative to the other major ethanol producers in Northern countries, are higher in Brazil due to higher soil productivity and greater sunlight intensity.

In China, sufficient regional solar resources combined with high electricity and gas costs (in particular regions) help to explain the success of the solar hot water market. China's solar insolation is 50,000 EJ (50,000 x 10^{18} J), which is about double the solar resources of a country such as the Netherlands, providing sufficient solar energy for the operation of simple and relatively inexpensive solar systems. The regions in China with the greatest penetration of solar hot water, such as Jiansu, Zhejian, Yunnan and Shandong, have the richest solar resources, as well as the most expensive gas and electricity sources. Regions with less solar radiation, such as Sichuan, have far smaller markets, indicating the important role of energy resources in spurring solar water markets in China.

Industrial Capacity and History of Innovation

In the case of Brazil and Mauritius, longstanding sugarcane production provided a technological base for the production and use of sugarcane-based fuels in power and transport. The marginal productivity gains made in sugarcane over the 30 years of the Proalcool programme (see Table 3) were accomplished in Brazil in the context of a longstanding sugar industry dating back to the country's inception. While government incentives have been important, the ethanol and auto industries have also improved efficiencies and learned to develop flexible approaches in the face of unstable prices and wavering government support. Ethanol producers have looked to exports to ensure stability in demand, and auto industries have developed 'flex fuel' cars to run on both gasoline and ethanol. Similarly, Mauritius has a 350-year history of sugarcane production, which has led to the most recent developments in electricity export from sugar plantations. In the case of Mauritius, gradual improvements in technology and organization, particularly related to operating pressure in bagasse burning, have led to steady and consistent efficiency improvements since 1971. By 2004, the industrial orientation had shifted from sugar factories exporting excess electricity to full power companies exporting continuous power from bagasse, alongside backup coal-burning facilities.

China, on the other hand, does not show the same related industrial experience relating to solar hot water systems. The solar hot water industry is only about ten years old in China, and its recent growth appears to be less an adaptation from a previously-established industrial sector, and more the development of a new market for domestic hot water, accompanied by growth in building construction and rising incomes. However, the solar hot water market has been built on the strength of China's light manufacturing sector and related capacities. Technological innovation has also occurred in the systems themselves in China (eg. vacuum tubes), and industry has been particularly astute in adopting new models for marketing and distributing solar hot water systems, to overcome barriers related to integration with existing housing and construction practices. Even so, these developments can be seen as a direct product of Chinese manufacturing and entrepreneurial strength, rather than the result a long-standing tradition of solar heating systems *per se*.

Policy

In all three cases, government policy played an important role in supporting market development through coordination and target-setting. Coordination was particularly important in integrating the activities of different sectors, as demonstrated in the role that governments have taken in coordinating ethanol and vehicle manufacture in Brazil, power companies and sugar companies in Mauritius, and solar water system vendors, developers and architects in China. In all cases, governments established plans with targets for research and development and market deployment. In the case of Mauritius, plans like the 1991 *Bagasse Energy Development Program*, brought in support from the World Bank, and acted to scale-up activities and coordination. Similarly, the Chinese government, with the assistance of the UNFIP, implemented the *Improvement and Expansion of Solar Water Heating Technology in China* program to help coordinate the expansion of the market and the integration of related sectors.

Brazil and Mauritius both subsidized the production of ethanol and electricity respectively, especially at early stages, and provided other tax exemptions, rebates and similar incentives for their respective markets. Brazil in particular invested heavily in market support for ethanol production as well as compatible vehicle production, and has recently modified incentives to foster stability in markets and diversification in demand through exports. Notably, the Chinese government did not intervene with any subsidies or fiscal incentives to support solar hot water, which was able to compete successfully with electric and gas water heaters in certain regions.

Socio-Political Attitudes and Values

Socio-political attitudes and perceptions appeared to play some role in promoting the market for renewable energies in the different countries. The perceived exacerbation of the balance of payments crisis in Brazil due to high oil prices in the 1970s appears to have provided an instrumental and resonant rationale for directing major financial resources to the Proalcool program for many years. Similarly in Mauritius, expanded policy support in the 1990s for bagasse electricity was prompted in part by the Gulf War, which increased the desire to reduce the country's fossil fuel dependence.

Local health benefits or reduced global greenhouse gas emissions did not appear to play a major role in motivating policymakers or citizens to support the technologies in any of the cases. The benefit of reduced greenhouse gas emissions has emerged more recently as a rationale for the expansion of the different schemes in each country, as climate change has emerged as a more prominent issue, and the UN Kyoto Protocol and Clean Development Mechanism have come into effect.

	Mauritius	**Brazil**	**China**
STATIC FACTORS			
Geography & Energy Resources	Abundant sugarcane resources/ no fossil fuel resources.	Abundant sugarcane resources/ high fossil energy dependence /high prices in 1970s and in recent years	Sufficient solar resources in key areas / high gas and electricity prices.
Industrial Capacity & History of Innovation	Adaptation from longstanding sugarcane industry/ 30 year history of efficiency gains/ shift from sugar factory to power company orientation.	Adaptation from longstanding sugarcane industry /30 year history of efficiency gains/ greater flexibility in industry.	New demand/ competitive market/light manufacturing strength/ greater integration with housing and construction.
DYNAMIC FACTORS			
Government Policy	Coordination, targets and fiscal and financial support.	Coordination, targets and fiscal and financial support.	Coordination & targets. No subsidies.
Social Attitudes & Values	Foreign energy dependence/ environmental concerns justify expanded and recent support.	Foreign energy dependence concern over balance of payments problems in the 1970s/ environmental concerns justify expanded and recent support.	Foreign energy dependence / entrepreneurial culture

Table 5 Factors Influencing Market Deployment in Mauritius, Brazil, and China

Policy Considerations

With the rapid increase in energy demand in developing countries and the emerging international consensus on the importance of increasing the contribution of renewable technologies, there is a growing need to examine strategies for the promotion of renewable energy in developing countries.

The case studies in Mauritius, Brazil and China illustrate the potential for developing countries to forge renewable energy markets and related industrial development on the basis of local planning, technological development and investment. In fact, the economic advantages of renewable technologies such as those described above, tend to become most apparent within the context of local conditions related to energy resources, industrial innovation and policy support - suggesting that the potential for developing renewable energies is best understood on a case by case basis, rather than looking at the generic costs or policy approaches for given technologies or through the lens of technology transfer alone. The cases do suggest the general importance of developing a full understanding of what could be called 'static factors', such as the historic nature of industrial capacities and the endowment of energy resources as a basis for capitalizing on more 'dynamic factors', such as emerging socio-political drivers relating to energy access, high international oil prices, or specific policy instruments such as the CDM.

While the combination of factors contributing to the success of each case is unique, there are some key points that can be distilled from the comparison that could lend general support to the promotion of renewable energies in developing countries through project planning and energy planning:

- The significant role of local renewable energy resource endowments in supporting market development points to the importance of national and local level planning and economic analysis, and renewable energy resource assessments in developing countries.

- The key role of technological adaptation from existing industrial capacities points to the impor tance of niche innovations, and of assessing existing industrial capacities and opportunities from which to launch or support renewable technologies in developing countries, as well as new tech nological development and technology transfer from industrialized countries.

- Governments play an indispensable role in coordinating between renewable technology companies, established service providers and infrastructure suppliers.

- Multilateral agencies often play an important role in scaling-up renewable energy markets once they have been initiated.

- Market-based policy support in the form of pricing, taxation and incentives, while important in most cases for promoting renewables, is not necessary in all cases -especially where the renew able technology fulfills a hitherto unmet demand or where zero fuel costs are immediately realizable by consumers.

- Robust renewable markets tend to be developed in conjunction with related fossil fuel technologies in order to cope with stable energy supply require ments and fluctuating energy prices and markets.

- The political fungibility of renewable energies fluctuates over time, and is driven mostly by political and public concerns over foreign energy de pendence, high energy prices and to a lesser but increasing extent, by environmental considerations and energy access.

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