Jamaica Sustainable Energy Roadmap

Pathways to an Affordable, Reliable, Low-Emission Electricity System

October 2013

WORLDWATCH INSTITUTE

Supported by:
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
based on a decision of the Parliament of the Federal Republic of Germany

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This project is part of the International Climate Initiative. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety supports this initiative on the basis of a decision adopted by the German Bundestag.

Suggested Citation: Shakuntala Makhijani, Alexander Ochs, et al., *Jamaica Sustainable Energy Roadmap: Pathways to an Affordable, Reliable, Low-Emission Electricity System* (Washington, DC: Worldwatch Institute, 2013).

On the cover: Wigton Wind Farm, Manchester, Jamaica. Photo courtesy of Mark Konold.

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Preface

Three years ago, Worldwatch approached the Jamaican Government with an idea: We suggested looking into the real costs—social, economic, and environmental—that the country was paying for its reliance on an energy system that was highly inefficient and almost exclusively dependent on the import of fossil fuels. We also proposed looking into alternative scenarios for energy development in the future. We wanted to help envision a system that was built on more-efficient consumption, domestic renewable resources, and smarter means of transmission and distribution. How much more—or less—would it cost? What social and economic impacts would it have? What would be the necessary investments? And what policy and institutional changes could make these investments flow?

The Jamaican Government was excited about the idea. Worldwatch had developed a methodology—the Sustainable Energy Roadmap—that we have since used in countries and regions around the world. The present study provides, for the first time, a complete Sustainable Energy Roadmap at the national level. We have done many sectoral assessments in recent years; published national and regional reports analyzing existing markets, technology trends, and policy developments; and assessed gaps in available information, research, communication, financial mechanisms, and policies. But this is the first-ever comprehensive Roadmap that describes where a country currently stands, where it can and should be in the future, and how it can get there.

We believe that this Roadmap provides decision makers and key energy-sector stakeholders in Jamaica with the sound technical, socioeconomic, financial, and policy analysis needed to guide the country's transition to a sustainable electricity system. Key findings and recommendations for institutional, regulatory, and legal reform are highlighted throughout the report. If implemented, they will usher in a new era of energy security, economic development, social progress, and environmental integrity.

The German Government provided the necessary support for this project with funds from its International Climate Initiative. Jamaica's carbon footprint is small by global standards, but the country is an important case study for at least two reasons. First, like most other small-island states, it is especially vulnerable to some of the most devastating climate change impacts, including sea-level rise, droughts, floods, and altered storm patterns. Shifting to a smarter energy system will help the country better adapt to these inevitable climatic changes. Second, Jamaica is strongly positioned to become a global leader in climate mitigation. It has vast domestic renewable energy resources—including solar, wind, hydropower, and biomass—that can be harnessed for electricity production. Energy efficiency measures such as building codes and appliance standards can greatly shrink Jamaica's future power demand, further reducing its reliance on imports of climate-altering fossil fuels.

Transitioning to a sustainable energy system will create jobs. It will increase the competitiveness of "green" business operations, including in the manufacturing and tourism sectors. And it will reduce emissions of local pollutants from fossil fuel burning, which harm human health and damage vital ecosystems. Following the pathways to an affordable, reliable, low-emissions electricity system laid out in this Roadmap will facilitate climate-compatible development in Jamaica, boost the nation's economy, reduce health costs and human suffering, and help preserve the island's unique environmental heritage.

Alexander Ochs
Director of Climate and Energy
Worldwatch Institute
Washington, D.C.
October 25, 2013

Acknowledgments

The Worldwatch Institute would like to thank the International Climate Initiative of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, whose financial support made this work possible. We are also grateful for the tireless support for this Roadmap from our partners at the Jamaican Ministry of Science, Technology, Energy & Mining (MSTEM), in particular Gerald Lindo and Fitzroy Vidal.

The authors thank Mirko Abresch, Anthony Chen, Stephen Curran, Catherine Gourdin, Mark Lambrides, Dr. Ruth Potopsingh, Denise Tulloch, and Robert Wright for their thorough review and feedback on the report. Additional valuable input was provided through interviews and by participants of our stakeholder consultation workshops in Kingston, notably David Barrett, Earl Barrett, Robert Boothe, Brian Casabianca, Michelle Chin Lenn, Mark Dennis, Edison Galbraith, Kwame Hall, Rohan Hay, Hopeton Herron, Richard Kelly, Yvonne Lewars, Maikel Oerbekke, Camille Rowe, and Shane Silvera. We especially thank Roger Chang of the Jamaica Solar Energy Association for his timely insights throughout this project on developments in Jamaica's energy sector.

3TIER was another instrumental partner in this work. Throughout the project, the 3TIER team provided unparalleled solar and wind resource information that would become a foundational piece of this initiative. They also went the extra mile to ensure that we understood how best to incorporate the data that they supplied. We owe a huge debt of thanks to Pascal Storck, Ken Westrick, Cameron Potter, Gwen Bender, and Charlie Wise for their professionalism, support, and assistance, and we look forward to future collaboration with the 3TIER team.

At Worldwatch, we would like to thank Katie Auth, Xing Fu-Bertaux, Evan Musolino, and Chris Flavin for their review and contributions to the report. Additional research and writing support were provided by Maria Cachafeiro, Ben Cohen, Dennis Hidalgo, Jiemei Liu, Natalie Narotzky, Reese Rogers, and Sam Shrank. Supriya Kumar supported outreach and communication efforts for this project, and Barbara Fallin and Mary Redfern provided vital administrative and institutional support. The patient review by Worldwatch Senior Editor Lisa Mastny and layout work by independent designer Lyle Rosbotham ensured a polished final Roadmap.

Finally, we wish to thank the many additional experts who cannot all be named here but who supported this project in diverse ways—by sharing ideas, providing us with access to data, and encouraging our work during the past three years.

Executive Summary

Jamaica's energy sector is at a crossroads. Currently, the country depends on petroleum imports for over 95% of its electricity generation, bringing enormous economic and environmental costs and necessitating a transition to a more sustainable energy system. In 2011, Jamaica spent 15% of its GDP on petroleum imports. Electricity prices for Jamaican residents are among the highest in the world, at around 40 U.S. cents per kilowatt-hour, having more than doubled between 2005 and 2011 as a result of rising global oil prices and electricity grid losses. The high price of electricity is a major barrier to Jamaica's economic development and a leading cause of business failure in the country. The reliance on fossil fuels for power generation also results in high local pollution and healthcare costs and contributes to global climate change.

The Jamaican government has considered diversifying Jamaica's energy mix by increasing imports of coal or liquefied natural gas (LNG). Although these energy sources could provide much-needed electricity cost reductions, the potential for energy efficiency measures and renewable energy generation deserve much greater consideration. In this Sustainable Energy Roadmap for Jamaica, the Worldwatch Institute conducts the technical, socioeconomic, financial, and policy assessments needed to create a smooth transition to an energy system that is socially, economically, and environmentally sustainable.

Energy Efficiency

The first element of Worldwatch's technical assessment is an analysis of key sectors for energy efficiency. Jamaica's high electricity costs mean that energy efficiency improvements can result in significant cost savings for the country, especially for large and energy-intense sectors. Improving the efficiency of power generation and reducing grid losses—both of which are far short of international standards—are a first step to reducing electricity prices for consumers.

End-use improvements and standards for key sectors can achieve significant additional energy savings. Despite its downturn in 2009, the bauxite and alumina industry continues to be one of Jamaica's largest energy consumers, yet there are still no equipment efficiency standards for the sector. Efficiency upgrades in the hotel and tourism industry provide another largely untapped opportunity, bringing significant demonstrated cost savings. Building codes and appliance standards can further improve efficiency in this sector, as well as reduce household energy consumption. Jamaica's single largest electricity consumer, the National Water Commission, has seen the benefit of reducing energy costs and is currently implementing measures to minimize water losses, conserve energy, and even produce its own power.

Renewable Energy

Improving energy efficiency will help curb the growth in energy demand in Jamaica, but new power capacity will still be needed to meet the country's needs. Jamaica has very strong renewable energy potential, and renewables could be used to meet the entire island's electricity demand. Domestic solar resources are particularly strong: average global horizontal irradiance (GHI)—the measure used to determine potential for solar photovoltaic (PV) development—ranges from 5 to 7 kilowatt-hours per square meter per day ($kWh/m^2/day$) throughout most of the country, with some areas nearing 8 $kWh/m^2/day$.

For perspective, Germany, which has nearly half of the world's installed solar PV capacity, has an average GHI of just 2.9 $kWh/m^2/day$ and very few locations above 3.5 $kWh/m^2/day$. Distributed solar PV generation at the household and commercial levels can play an especially important role in Jamaica's energy mix.

Several locations in Jamaica have extremely strong wind energy potential. The successful experience of the country's Wigton Windfarm could be replicated at other sites that have high wind speeds. Just 10 medium-sized wind farms (60 megawatts each) could provide more than half of Jamaica's current power demand. Wind energy potential varies throughout the day and year, but several locations could still support economical wind power generation even during relative lows.

By developing small hydropower potential at Jamaica's remaining viable sites, and improving the efficiency of existing sugarcane bagasse power generation in order to connect these facilities to the national grid, the country can round out a diverse, renewables-based electricity system.

Electricity Grid

To reduce grid losses and accommodate growing energy demand, Jamaica's electricity grid will require significant upgrades and expansion. Distributed generation, especially from household and commercial-scale rooftop solar PV systems, can reduce power-system inefficiencies by avoiding grid losses. The technical challenges associated with distributed generation, such as unintentional islanding and voltage fluctuations, can be addressed using well-established technologies, operating standards, and regulatory best practices. Furthermore, a distributed electricity system based on renewable energy will be more resilient than centralized fossil fuel generation is to climate change impacts, such as more frequent and intense hurricanes, to which Jamaica is particularly vulnerable as a small-island state.

Important grid modernization measures, such as replacing Jamaica's aging grid with higher-voltage transmission lines and improving operations and forecasting practices, can go a long way to addressing challenges associated with the variability of renewable energy. In most cases, the cost of grid connection for solar, wind, and small hydro installations will be minimal and should not serve as a deterrent to renewable energy planning.

Jamaica's current electricity system is well suited to renewable energy integration, as existing diesel and fuel oil power plants can be quickly fired up and down in response to fluctuations in solar and wind generation. New natural gas plants, if installed, would similarly complement variable renewable power production. Integrating multiple renewable energy sources can further reduce renewable intermittency issues—in Jamaica's case, combining solar and wind capacity on the grid can help particularly in smoothing out seasonal variability. In addition, electricity storage options, especially batteries and pumped hydro systems, can be paired with renewable energy capacity to store power produced during periods of high production and low demand, to be fed into the grid at peak hours.

Energy Scenarios Through 2030

If the necessary grid strengthening measures are implemented, renewable energy can reliably meet more than 90% of Jamaica's electricity demand while lowering energy costs. Worldwatch developed several scenarios for scaling up renewables in the country's electricity sector through 2030. These scenarios present technical realities of the different energy pathways that Jamaica is considering, including importing LNG or coal for power generation. Worldwatch's analysis shows that a transition to an energy system based on renewable energy is best achieved through integration with the current petroleum-based power system.

Alternatively, new natural gas power plants can secure electricity demand in the transitioning period, particularly if investments in renewables do not take off as quickly as needed. There are several barriers to natural gas development in Jamaica, however, in particular the need to find a supplier for LNG and the high upfront costs of building import terminals and pipeline distribution infrastructure.

In contrast to petroleum and gas power, investments in new coal plants will ultimately limit the amount of renewable energy that the system can integrate. Because coal plants are relatively inflexible and, unlike petroleum and gas power, cannot be rapidly fired up or down in response to renewable power fluctuations, new coal power in Jamaica would result in much higher curtailment at times of peak renewable production.

Socioeconomic Impacts

Worldwatch built on its technical resource assessments to model the costs of electricity production from various energy sources from 2013 through 2030. Based on findings from this socioeconomic assessment, renewable energy can enable Jamaica to lower surging electricity prices, save scarce resources on fossil fuel imports, decrease its trade deficit, increase energy security, and reduce greenhouse gas emissions and local pollution at negative costs.

At generation costs of just over 5 and 10 U.S. cents per kWh respectively (not including financing costs), new hydro and wind power facilities are already competitive energy sources in Jamaica today (compared to petroleum at 15 to over 30 U.S. cents per kWh), and comparable to projected costs of natural gas and coal generation. Solar will become the cheapest source by 2030 if the country is able to benefit from experience and economies of scale. Once external health, environmental, and climate change costs of fossil fuel generation are factored in, the economic case for all renewable energy sources becomes even stronger.

Applying electricity cost assessments to Worldwatch's scenarios through 2030 for Jamaica demonstrates that a higher share of renewable energy reduces overall energy costs across all scenarios. A continued reliance on the current oil-based generation infrastructure during the shift to renewable energy requires less upfront investment and results in high greenhouse gas emission savings, but also leads to high fuel costs and overall generation costs in the transition period.

Investments in new coal power, on the other hand, do not reduce greenhouse gas emissions compared to a business-as-usual approach, reducing the health and environmental sustainability benefits and limiting channels for accessing climate finance and other energy-sector development aid. The use of natural gas as a transition fuel provides the greatest cost savings in Worldwatch's scenario analysis, but this analysis does not include the costs of building the necessary import and distribution infrastructure, and also depends largely on a favorable import price for LNG.

An assessment of the comparative macroeconomic benefits of Worldwatch's different scenarios to achieving a more sustainable electricity sector further underlines the importance of this shift. Transitioning to an electricity system powered almost exclusively by renewables can decrease the average cost of electricity by 67% by 2030 in comparison to 2010. The transition also can create up to 4,000 new additional jobs and reduce greenhouse gas emissions in the electricity sector to a mere 0.7 million tons of CO_2-equivalent annually. Although an accelerated expansion of renewables requires higher upfront investments, it reduces the total cost of electricity generation and can save the country up to USD 12.5 billion by 2030, freeing up public money to be spent on more pressing social and economic concerns.

Sustainable Energy Finance

Worldwatch's scenario cost analyses demonstrate that Jamaica could reach 93% renewable electricity generation by 2030 with less than USD 6 billion in investment costs between 2013 and 2030 (compared to over USD 2 billion spent on oil imports in 2011 alone). However, persistent high interest rates and a lack of access to long-term loans needed to cover the upfront capital costs of energy efficiency and renewable energy projects have hampered development of Jamaica's sustainable energy market. Despite these barriers, the investment climate for sustainable energy in the country is improving. Interest rates have fallen significantly in recent years, and in 2013 Jamaica reached a renegotiated agreement with the International Monetary Fund that will help reduce financial uncertainty in the country.

In addition, several energy credit lines disbursed through the Development Bank of Jamaica provide low-interest loans for sustainable energy projects, especially for small and medium-sized enterprises. The ability of domestic financial institutions to provide loans for energy efficiency and renewable energy is strengthening as banks become more familiar with Jamaica's growing renewable energy market.

Perceived risk and the need for capacity building impede domestic investment in sustainable energy. Private international finance institutions also continue to view Jamaica's sustainable energy market as risky, and for the most part they will not provide loans without assurance through a sovereign guarantee from the Jamaican government that debts will be repaid.

Outside of private financial institutions, traditional development assistance from bilateral and multilateral agencies is targeted increasingly toward sustainable energy. Jamaica can harness these resources to establish energy efficiency and renewable energy programs. Climate financing—including through Nationally Appropriate Mitigation Actions (NAMAs), Climate Investment Funds, and the Green Climate Fund—also has the potential to provide major support for Jamaica's sustainable energy transition.

Although a high share of renewable energy will be more cost effective than fossil fuels over the entire lifecycle of new power installations, the relatively high installment costs for renewables remains an important challenge. Further improvements in the financial sector will thus be necessary to make use of Jamaica's full renewable energy potential. These include capacity building for banks and project developers, creation of new loan products, and financial guarantees to improve investment security in the sustainable energy market.

Policy Recommendations

Although creative financing solutions can overcome some challenges, the most significant barriers to achieving a sustainable energy transition in Jamaica must be overcome through smart policies. In 2009, Jamaica established its National Energy Policy, which includes a commitment to providing 20% of the country's energy from renewable resources by 2030; the Jamaican government has since committed to increasing this goal to 30%. Based on Worldwatch's renewable resource potential assessments and energy scenario cost analyses, however, we conclude that Jamaica can strengthen its renewable energy target for the electricity sector to 90% or more by 2030 while also reducing electricity prices for consumers.

Overarching national energy plans and targets are just one part of the planning and policy framework necessary for a sustainable energy transition, and these alone are not enough to ensure that all goals will be met. Institutional and regulatory barriers currently stand in the way of achieving a significant share of renewable energy in Jamaica. In particular, the Office of Utilities Regulation (OUR), the country's electricity regulator, has fallen far short of its mandate to increase renewable energy capacity and to maintain affordable electricity prices in Jamaica.

A new electricity policy and accompanying legislation are necessary to strengthen OUR's directives and the Ministry of Science, Technology, Energy & Mining's (MSTEM) authority over the electricity sector. Current efforts by MSTEM—including the Modernize Electricity Act—to take on electricity planning and procurement and to strengthen oversight of OUR's regulatory authority should be supported to ensure that Jamaica meets its renewables targets. Stronger electricity-sector regulation is also required to demand that the Jamaica Public Service Company (JPS), the national utility, sets fair prices that accurately reflect generation costs and enable access to reliable, affordable energy for consumers and businesses.

Time-consuming administrative procedures for energy projects are also a major deterrent to renewable development in Jamaica. Although effective permitting is essential to limit the negative environmental and social impacts of energy projects, long and bureaucratic permitting processes can result in significant risk and expense, discouraging developers and investors from undertaking renewable projects. Streamlining permitting procedures would eliminate a major source of renewable energy investment risk.

Jamaica currently has several policies proposed or in place to promote energy efficiency and renewable energy, including building codes, appliance standards, net billing, electricity wheeling, and a competitive tendering process for renewable capacity. In the near term, these measures should be implemented to their fullest potential to demonstrate the government's commitment to sustainable energy. In the longer term, policies that have been proven successful in other countries—including net metering programs and renewable feed-in tariffs—should provide additional support for Jamaica's energy transition.

Jamaica's government, private industry, and civil society have acknowledged the important role of energy efficiency and renewable energy in reducing energy costs, bolstering the economy, and contributing to a healthier environment. The country is now at a crucial point where it must implement targeted measures and reforms in order to achieve the full benefits of a sustainable energy system in the coming years.

1 | Developing a Sustainable Energy Roadmap for Jamaica: An Integrated Approach

Key Findings

- Jamaica's electricity sector is dominated by oil, with petroleum fuel accounting for 95% of the country's power generation.
- Despite the government's commitment to increasing renewable energy, Jamaica's energy diversification strategies are currently focused on coal and natural gas.
- Jamaican consumers pay some of the highest electricity prices in the world, at nearly 40 U.S. cents per kWh for residential customers; electricity prices in Jamaica more than doubled between 2005 and 2011, driven by increasing global oil prices, generation inefficiency, and electricity grid losses.
- High electricity costs are a leading cause of business failure in Jamaica.
- Jamaica spent USD 2.2 billion on petroleum imports in 2011, equivalent to 15% of GDP.
- International support for climate change mitigation and access to sustainable energy can provide an opportunity for Jamaica to deploy energy efficiency measures and harness its strong renewable energy potential.
- In order for Jamaica to transition to a sustainable energy system, a holistic approach is needed that assesses technical potentials for efficiency, renewable energy, and grid improvements; socioeconomic benefits of renewable energy; opportunities for financing sustainable energy projects; and, most importantly, policy recommendations for how to implement the shift to a clean, affordable energy supply.

Energy roadmaps are important guideposts to a country's aspirations for economic progress. At the same time, they sketch out opportunities for a country to contribute to international efforts to strike a more sustainable, climate-friendly development path.

The first chapter of this report provides international context for this endeavor and outlines key features of a modern, low-emissions energy system in Jamaica as well as the methodology for developing a roadmap to get there. It describes the country's current electricity system as well as the key challenges to advancing this system toward greater independence and sustainability.

1.1 Jamaica's Sustainable Energy Transition in the Global Context

At the 2009 and 2010 Conferences of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), held in Copenhagen, Denmark, and Cancún, Mexico, advanced economies pledged to provide developing countries USD 30 billion in financial and technical assistance for climate change adaptation and mitigation by 2012, and USD 100 billion annually by 2020.[1]* These efforts are supported by the international development community, including the World Bank, regional development banks, and other international and bilateral mechanisms.

These assistance measures reinforce earlier agreements made at the 2007 UN Climate Change Conference in Bali, Indonesia. According to the *Bali Action Plan* (commonly known as the Bali Roadmap), developing countries are to consider "[n]ationally appropriate mitigation actions…in the context of sustainable development, supported and enabled by technology, financing and capacity-building." The activities of developing countries, as well as the technology transfer and financial assistance efforts of industrial countries, are to be implemented in a "measurable, reportable and verifiable manner."[2]

Small-island states have played a proactive role in international climate negotiations. At the Copenhagen conference in December 2009, member countries of the Alliance of Small Island States (AOSIS) launched a sustainable energy initiative known as SIDS DOCK, designed as a "docking" station to connect the energy sectors in these countries to wider markets for finance, carbon, and sustainable energy sources. SIDS DOCK commits small-island states to work together to develop renewable energy and energy efficiency options and to seek funding from international carbon markets to implement their low-carbon energy strategies.

Additionally, UN Secretary-General Ban Ki-moon launched the Sustainable Energy for All initiative in 2012, with three central objectives through 2030: "providing universal access to modern energy services; doubling the global rate of improvement in energy efficiency; and doubling the share of renewable energy in the global energy mix."[3] The Sustainable Energy Roadmap for Jamaica provides the country with a clear pathway to meeting these goals and accessing opportunities under the initiative.

Historically, developing countries have contributed comparatively little to the world's climate crisis. Yet these nations are profoundly vulnerable to the impacts of climate change, including water shortages, reduced food production, and escalating disasters due to increased storm intensity and rising sea levels. Meanwhile, developing-country emissions are growing rapidly, with their combined share of global greenhouse gas output expected to soar in coming decades unless new approaches are taken to develop low-emissions energy, building, and transport systems. Most developing countries, including small-island states, currently lack the technologies and policies needed to pursue an alternative, less emissions-intensive path.

In addition to providing environmental benefits, low-emissions development strategies can deliver socioeconomic benefits by taking advantage of indigenous renewable energy resources such as solar, wind, hydropower, geothermal, and biomass, rather than relying on imported fossil fuels. Small-island states can serve as ideal showcases for low-carbon development strategies due to the congruence of their national economic and security interests with the global climate agenda, as well as to their relatively small sizes and the homogeneity of their economies. With adequate support, they can demonstrate on a small scale what needs to be done globally in the long run.

Technologies that are available today, and those that are expected to become competitive in the next few

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* Endnotes are numbered by chapter and begin on page 149.

years, can permit a rapid decarbonization of the global energy economy if they are deployed properly.[4] Modern sustainable energy systems are built on an advanced degree of energy efficiency, a high share of renewable energy in the overall electricity mix, and a strong and flexible grid structure. Additional key components to increasing energy and economic security include the diversification of energy sources and suppliers, a decrease in the level of energy imports, and greater infrastructure stability during natural disasters.

As a country particularly vulnerable to destructive weather events, Jamaica needs to develop a stable energy infrastructure that can withstand natural disasters, particularly hurricanes and tropical storms. Coal and nuclear power pose serious environmental and safety risks, especially in a disaster-prone region like the Caribbean. Electricity from natural gas can be fed into the electricity grid with much greater flexibility than coal and nuclear baseload power, and it has the benefits of greater efficiency and lower carbon emissions than electricity generated from oil. Therefore natural gas could potentially play an important role as a natural ally of renewable power by compensating for the variability and storage challenges that currently exist with renewables.[5] Natural gas should be used as a part of a larger strategy to transition to renewable energy, however, as reliance on gas as the centerpiece of the energy sector will prolong dependence on fossil fuel imports.

Like most countries in the world, Jamaica has enormous renewable energy resources. In order to harness them, however, an intelligent framework of policies and regulations is needed. Low-carbon energy strategies require the implementation of solutions that are physically available, economically viable, and politically feasible.

1.2 Sustainable Energy Roadmap Methodology: Goals and Challenges

This Roadmap is the result of an intensive, multi-year research project on how to seize opportunities and overcome existing barriers to a sustainable energy transition in Jamaica. Because energy infrastructure decisions are decisive for a country's development and involve difficult tradeoffs, it was essential to gather the latest high-quality data as well as to understand the interests and opinions of all of the parties that will be critical to making the proposed ambitious energy plan a reality.

Worldwatch's Sustainable Energy Roadmaps use a multi-pronged approach, combining technical assessments of a country's renewable resource base with in-depth research, evaluation of specific technological and economic issues, and analysis of existing and potential policies, while weighing different examples of international best practice.

From the outset, Worldwatch worked closely with Jamaican officials and partners to ensure that the scope of work will complement, not duplicate, all previous efforts in renewable energy integration and grid planning policy. Previous studies have looked at different aspects of the potential for energy efficiency and renewables in Jamaica and the Caribbean region. Although these studies all served as important references for this project and provided essential information about different parts of the renewable energy picture, a comprehensive overview of efficiency and sustainable energy options and strategies at the country level was lacking. This Worldwatch Roadmap aims to fill this information gap.

The Worldwatch Roadmap methodology takes a holistic approach to assessing the interdependent components of a country's clean energy potential. (See Figure 1.1.) We identify opportunities for increased efficiency, examine a country's renewable resource potential for renewable energy production, and catalogue grid enhancement and extension needs and energy storage solutions. The Roadmap also identifies socioeconomic impacts of a sustainable energy transition, including electricity costs and job creation potentials. The Roadmap then highlights private, public, and multilateral funding options to make renewable energy plans a reality. Finally, the Roadmap highlights policy barriers to renewable energy development and relies on international best practice to suggest how they can be overcome. Worldwatch is also committed to capacity building and knowledge sharing at all levels of government and civil society to help policymakers successfully implement our recommendations.

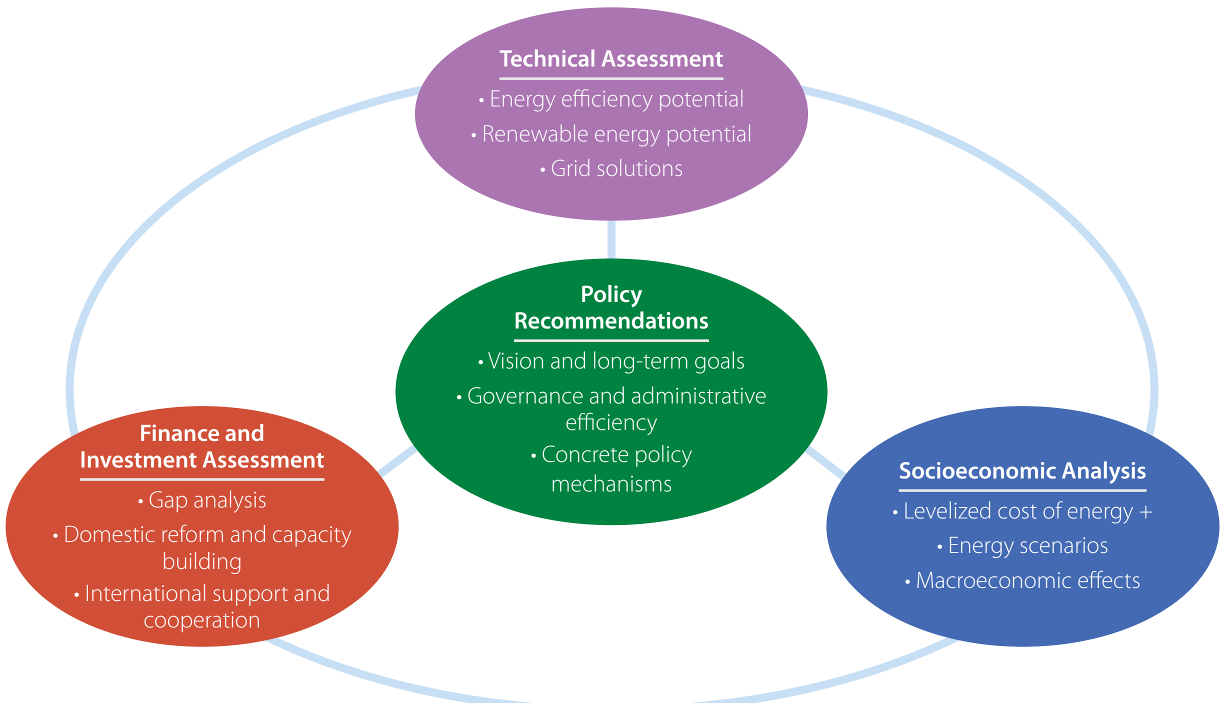

Figure 1.1

Worldwatch Methodology for Sustainable Energy Roadmap Development © *Worldwatch Institute*

This report presents the most detailed assessment ever undertaken of wind and solar resources in Jamaica. Worldwatch has partnered with 3TIER, Inc., a renewable energy risk-analysis company that develops high-resolution mapping and data, to gain access to comprehensive wind and solar resource datasets. In the Caribbean, as elsewhere, weather patterns may change over time. Thus, it is important to capture the long-term variability of wind and weather so that observations are not one-time inventories, but can be placed in the proper historical context. 3TIER's simulation also captures the spatial detail of the wind and weather resource, an important factor in accelerating the process of prospecting and screening for potential renewable energy development sites, especially in areas of complex mountainous terrain.

The report also provides an overview of other energy resources in Jamaica, including small hydropower, biomass, and municipal solid waste. Worldwatch drew from previous resource analyses and partnered with ongoing assessment efforts to provide the most comprehensive and recent data on energy potentials.

The first step in the Roadmap for identifying sustainable energy opportunities in Jamaica is to pinpoint areas for increased energy conservation and efficiency. By targeting high-consuming and energy-intensive economic sectors, Chapter 2 of this roadmap demonstrates key leverage points for reducing the country's energy needs.

An essential next step was the production of country-wide maps visualizing the solar and wind resources in Jamaica. Based on these initial assessments, and on intense discussion with the government, solar and wind zones were defined, which were then profiled in depth. The 3TIER wind and solar assessments, as well as other renewable resource analyses, are presented in Chapter 3 of this study. 3TIER's more-detailed individual assessments are included in Appendix I.

The Roadmap focuses on cost-effective ways to integrate indigenous renewable resources into a strong and reliable national energy grid. This technical analysis also allows us to catalogue the grid enhancement and extension that increased use of renewable energy could require. The technical assessment presented in Chapter 4 of this report is the result of consultations with in-country experts and relates infrastructure needs to the findings from the resource assessment undertaken in this as well as other studies.

An in-depth analysis of the socioeconomic benefits and impacts of transitioning to renewable energy will help decision makers make the case to energy developers, investors, and the public that harnessing these domestic resources is in Jamaica's best interest. Chapter 5 of this study presents detailed scenario analyses of potential energy pathways that Jamaica can take, demonstrating the feasibility of high renewable energy penetration. Chapter 6 builds on these scenarios to present the costs of electricity generation from various fossil fuel and renewable energy sources in Jamaica based on locally gathered data. It also applies the renewable assessments in Chapter 3 to estimate the job-creation potential of developing these resources.

Chapter 7 identifies domestic and international sources of private and public financing for renewable energy resources, including how to overcome existing barriers to achieving the level of investment needed for a sustainable energy transition. The project team conducted a thorough survey of existing energy laws and regulations. Drawing on international best practice and lessons learned, Chapter 8 discusses opportunities for policy reforms, looking both at key principles that should guide successful renewable policymaking as well as at concrete policies and measures. The chapter also identifies important administrative support mechanisms and potential sources of finance to support these efforts.

Throughout the project, Worldwatch has engaged in local capacity building and knowledge sharing. We have held workshops, participated actively in conferences, and engaged in one-on-one conversations to bring stakeholders together and to bridge knowledge gaps between government, private renewable energy investors, utilities, and the financial sector. Worldwatch has used blogging and other social media efforts to further communicate our findings. This final Roadmap will be presented to local stakeholders in Jamaica as a concrete tool that they can use for planning and implementation of new renewable energy policies and projects.

1.3 Jamaica's Current Electricity System

In Jamaica, the Ministry of Science, Technology, Energy and Mining regulates the energy industry as a whole and works to promote efficiency, diversification, and competitiveness of the energy market.[6] MSTEM monitors energy supplies by overseeing the activities of the Petroleum Corporation of Jamaica (PCJ), a state-run energy corporation that manages petroleum refining and distribution, as well as guiding renewable energy development and energy efficiency projects in the public sector.

The Jamaica Public Service Company (JPS), the country's grid operator, has a 20-year monopoly (to 2027) on electricity transmission and distribution in the country through the 2001 All-Island Electricity License, although the Supreme Court of Jamaica recently invalidated the exclusive license.[7] (See Chapter 8.) Formerly a public sector company, JPS was privatized in 2001 and is now 80% privately held and 20% government owned.[8] JPS is regulated by the Office of Utilities Regulation (OUR), an independent regulatory agency.[9]

Jamaica's energy system is dominated by imported petroleum, which accounted for 95.3% of the country's total electricity generation in 2009.[10] (See Figure 1.2.) Renewable energy sources comprised 4.8 percent of total generation that year, with the bulk of this coming from hydropower.[11] Since 2004, the country has also generated a small amount of power from the wind (as well as from biomass, most of which is not connected to the grid and is therefore not reflected in official statistics).

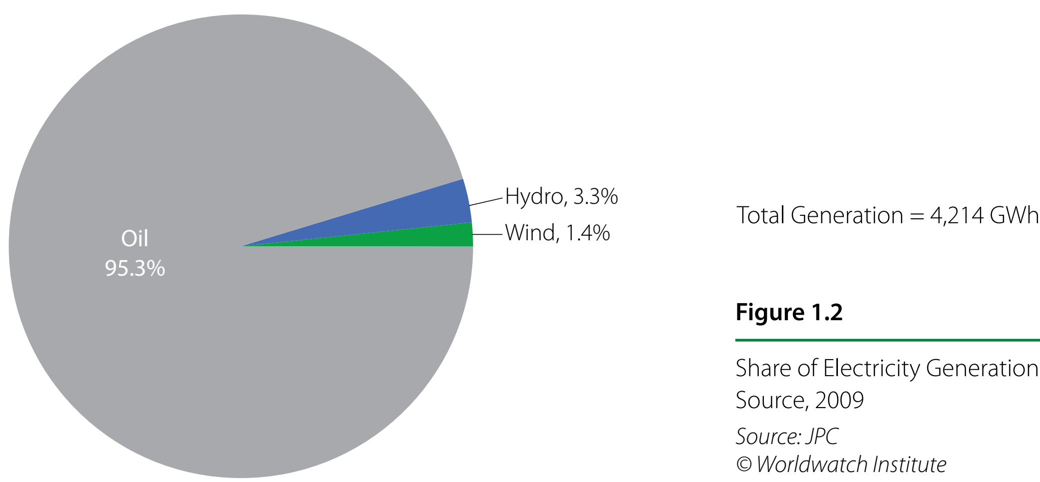

Figure 1.2

Share of Electricity Generation by Source, 2009

Source: JPC
© Worldwatch Institute

Electricity generation accounts for the greatest share of petroleum consumption in Jamaica, at 31%, followed by road and rail transportation (28%) and bauxite and alumina processing (18%).[12] (See Figure 1.3.) Electricity generation totaled 4,137 GWh in 2011, down from a peak of 4,214 GWh in 2009.[13] Total generation increased at an average annual rate of 3.3% from 1998 to 2009.[14]

Peak demand in 2011 occurred in August and reached 617.7 megawatts (MW).[15] To date, the highest peak demand in Jamaica is 627.5 MW.[16] Although meeting the country's electricity needs with renewable energy might seem like a daunting task, Jamaica's peak demand is just a fraction of the new renewable capacity being installed worldwide each year. In 2011 alone, the world added 30 gigawatts (GW) of solar

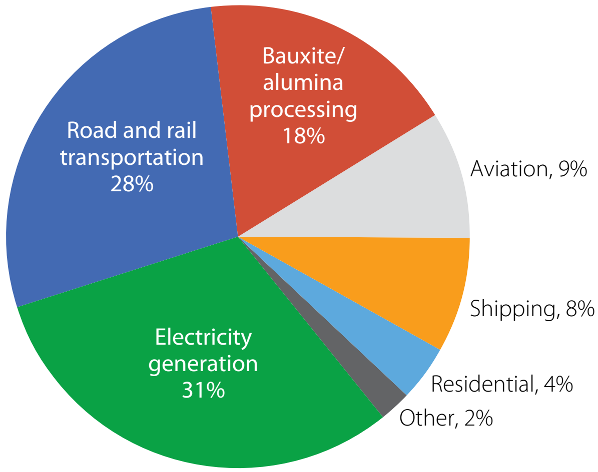

Figure 1.3

Share of Petroleum Consumption by Activity, 2010

Source: MSTEM

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photovoltaic (PV) capacity to reach 70 GW total, and 40 GW of wind capacity to reach 238 GW total. Global solar PV and wind capacity additions in 2011 alone were more than 1,000 times greater than Jamaica's highest electricity demand to date.[17]

Jamaica has 925.2 MW of installed electricity capacity, 625.6 MW (or 68%) of which is operated by JPS; the rest is operated by the country's four independent power producers (IPPs): Jamaica Energy Partners, Jamaica Private Power Company, Wigton Windfarm, and Jamalco.[18] (See Table 1.1.) Sugarcane and bauxite and alumina industries also generate some of their own electricity, which is not currently sold on the national grid. The dominance of JPS and the small number of IPPs demonstrates that there is little competition in the electricity generation sector, especially considering JPS's control of Jamaica's electricity grid.

Just under 600 MW of JPS's 625.6 MW of capacity consists of petroleum-based power plants (running on diesel and/or heavy fuel oil) at four sites: Old Harbour (223.5 MW), Bogue (217.5 MW, of which 114 MW is combined-cycle generation), Hunt's Bay (122.5 MW), and Rockfort (36 MW). JPS's remaining 26 MW of capacity comprises eight run-of-river small hydro units (23 MW) and the 3 MW Munro Wind Farm.

Heavy fuel oil is a particularly dirty energy source, as it is a residual fuel that is left after more valuable forms of crude oil are separated out. In addition to high carbon emissions, it contains a high concentration of sulfur and other elements that contribute to more-polluting emissions upon combustion.

Power production from Jamaica's IPPs is similarly dominated by heavy fuel oil and diesel. The largest IPP, Jamaica Energy Partners, owns 189.9 MW of diesel and heavy fuel oil capacity.[19] Jamaica Private Power Company owns 60 MW of diesel capacity.[20] Wigton Windfarm, a subsidiary of the Petroleum Corporation of Jamaica (PCJ), operates 38.7 MW of wind capacity.[21] Jamalco, a bauxite and alumina company, has its own electricity generation facilities and provides 11 MW of heavy fuel oil capacity to JPS for the national grid.[22]

As Table 1.1 indicates, Jamaica's existing power plants are aging. At Old Harbour, for example, the last steam unit was commissioned in 1973, making all four of the facility's units at least 40 years old. Jamaica's Office of

Table 1.1. Existing Power Plants, as of June 2013

Location	Owner	Fuel/ Energy Source	Capacity	Date of Commission*
			megawatts	
Old Harbour Bay (St. Catherine)	JPS	Heavy fuel oil	223.5	1968 to 1973
Bogue (St. James)	JPS	Automotive diesel oil	217.5	1973 to 2003
Old Harbour Bay (St. Catherine)	Jamaica Energy Partners	Diesel and heavy fuel oil	124.4	1995 and 2006
Hunt's Bay (Kingston)	JPS	Automotive diesel oil and heavy fuel oil	122.5	1974 to 1993
West Kingston	Jamaica Energy Partners	Medium-speed diesel	65.5	2013
Rockfort (near Kingston Harbour)	Jamaica Private Power Company	Slow-speed diesel	60.0	1997
Manchester	Wigton Windfarm	Wind	38.7	2004 and 2011
Rockfort (St. Andrew)	JPS	Automotive diesel oil	36.0	1985
Clarendon	Jamalco	Heavy fuel oil (oil-fired steam)	11.0	1972
Maggoty (St. Elizabeth)	JPS	Run-of-river hydro	6.0	1959
Lower White River (St. Ann)	JPS	Run-of-river hydro	4.8	1952
Roaring River (St. Ann)	JPS	Run-of-river hydro	4.1	1949
Upper White River (St. Ann)	JPS	Run-of-river hydro	3.2	1945
Munro (St. Elizabeth)	JPS	Wind	3.0	2010
Rio Bueno A (Trelawny)	JPS	Run-of-river hydro	2.5	1966
Rio Bueno B (Trelawny)	JPS	Run-of-river hydro	1.1	1988
Constant Spring (St. Andrew)	JPS	Run-of-river hydro	0.8	1989
Rams Horn (St. Andrew)	JPS	Run-of-river hydro	0.6	1989

** Each petroleum generation site has multiple power plants, some commissioned at different dates.*

Utilities Regulation found that all of the units at Old Harbour "have surpassed their useful economic life."[23]

Jamaica has an electrification rate of 98%, which means that the grid reaches the majority of the country's population, although a noteworthy share continues to lack electricity access.[24] Transmission and distribution losses on the grid network are significant, totaling 22.3% in 2011, although down slightly from 24.7% in 2008.[25] Losses resulted in a difference of 961.4 GWh between electricity produced and sales, the latter of which totaled 3,175.6 GWh in 2011.[26] Transmission and distribution losses comprise both technical losses (about 10% of total generation in Jamaica) and non-technical losses.[27]

Consumers in Jamaica pay a high price for electricity, especially compared to elsewhere in the region and around the world.[28] (See Figure 1.4.) Electricity prices in U.S. cents per kilowatt-hour (kWh) in 2011 for the various consumer categories were: 41.7 cents for street lighting, 38.8 cents for small commercial users, 37.6 cents for residential customers, 33.2 cents for large commercial users, 31.0 cents for industrial users, and 29.0 cents for other consumers.[29] For most customers in Jamaica, electricity prices more than doubled between 2005 and 2011.[30] (See Figure 1.5.)

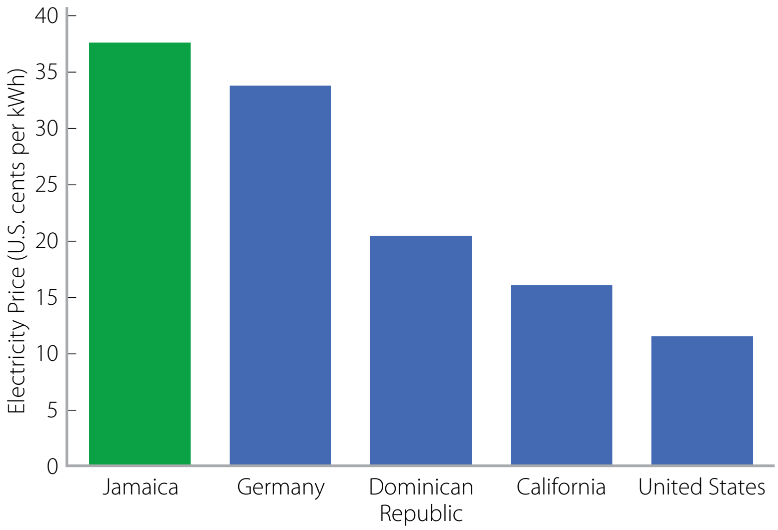

Figure 1.4

Electricity Prices for Residential Consumers, 2011

Source: MSTEM, T&TEC, EIA, EC
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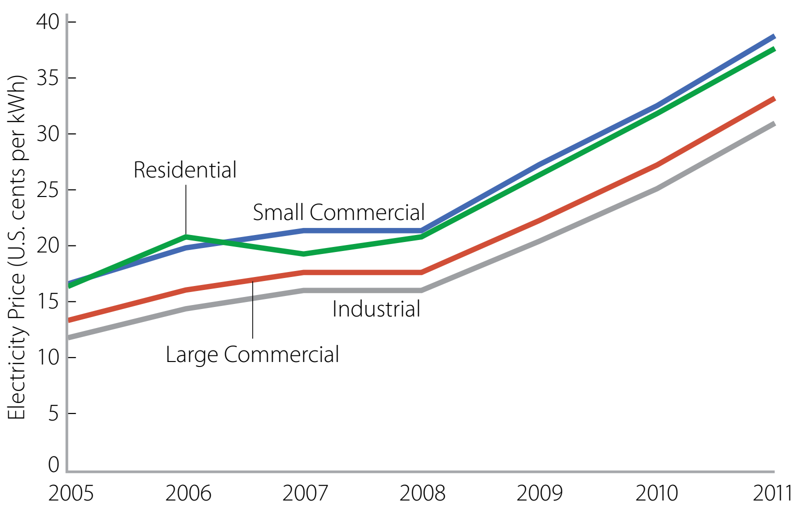

Figure 1.5

Electricity Prices in Jamaica by Sector, 2005–2011

Source: MSTEM
© Worldwatch Institute

In addition to high electricity bills for households, elevated electricity prices hamper Jamaican industry, making it difficult for manufacturing to remain competitive in the region. As a result, Jamaica is now one of the largest markets for goods manufactured in Trinidad and Tobago, where electricity prices are just 5–6 U.S. cents per kWh.[31]

A 2011 survey of micro, small, and medium-sized enterprises in Jamaica found that high electricity costs are a leading cause of business failure in the country. Of respondents who were past business owners, 73% indicated that high electricity costs contributed to business failure, and 38% stated that high electricity costs played a role in the decision to close the business.[32] Similarly, a 2003 competitiveness study by the Jamaica Manufacturers' Association found that the cost of electricity is the largest competitive disadvantage in Jamaica's local productive sector, as compared to regional competitors Costa Rica and Trinidad and Tobago.[33]

Residential customers account for one-third of electricity consumption, with commercial and industrial customers comprising most of the remaining two-thirds.[34] (See Figure 1.6.) The significant share of residential electricity consumption provides a key opportunity for on-site distributed power generation, especially from solar PV systems. Similarly, commercial consumption is driven largely by electricity use in the hotel and tourism sector, which, combined with high electricity prices, creates a strong incentive for energy efficiency measures and distributed solar generation.

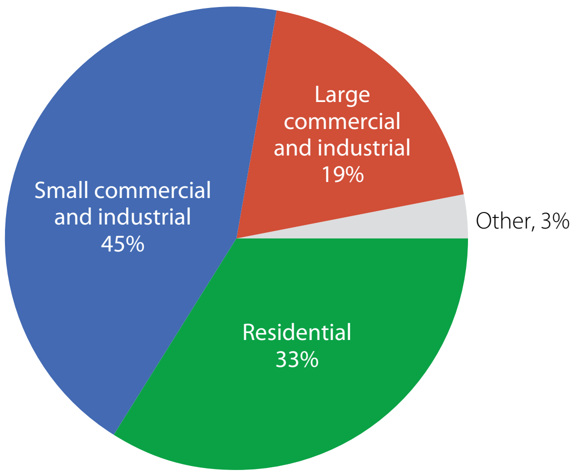

Figure 1.6

Share of Electricity Sales in Jamaica by Sector, 2011

Source: JPS
© Worldwatch Institute

High global oil prices led to a general downward trend in petroleum imports to Jamaica in the five years from 2007 to 2011, falling from 29.9 million barrels to 21.2 million barrels (up slightly from a low of 20.5 million barrels in 2010).[35] Rising oil prices up until the global economic recession led to a peak in Jamaica's petroleum import costs in 2008 at USD 2.7 billion, or 19% of GDP that year.

Import costs remain high at USD 2.2 billion in 2011, or 15% of GDP, and can be expected to increase further as oil prices rise in the future. The share of oil import costs for electricity generation have been increasing steadily even since the oil price peak, growing from USD 617 million in 2008 to USD 678 million in 2011—or nearly 5% of GDP for electricity fuel imports alone.[36] These costs are even more striking when compared with Jamaica's export revenues, which totaled USD 1.65 billion in 2011, significantly less than Jamaica's oil import costs that year.[37]

Jamaica has several projects for additional electricity capacity in the planning and construction phases. Plans for new capacity aim at diversifying the country's generation mix away from petroleum-based fuels. Until recently, the strategy relied mostly on new large liquefied natural gas (LNG) power plants, as well as new renewable capacity.

Since current energy diversification plans were announced in 2009 under the National Energy Policy, LNG prices in the region have increased, and it is no longer clear whether JPS and other LNG consumers will be able to procure supplies at a feasible cost. JPS previously had been counting on a price of USD 8.50 per million British thermal units (Btu), a price that is no longer considered realistic for Jamaica.[38] According to one LNG expert, even in a favorable buyers' market the cost of LNG in Jamaica is estimated at USD 10–12 per million Btu.*[39] Perhaps more significantly, the upfront costs of building an LNG import terminal and pipeline infrastructure would cost Jamaica hundreds of millions of dollars.[40]

In October 2012, the Jamaican government disbanded its steering committee to oversee LNG projects, and in January 2013 it withdrew its commitment to LNG.[41] In February 2013, OUR withdrew from its agreement with JPS to build a 360 MW LNG combined-cycle plant at Old Harbour.[42] With LNG an increasingly uncertain energy option, in early 2013 the Government of Jamaica expressed support for coal as an alternative energy source, although new coal capacity in the country is not expected to come on line for at least a few years.[43]

1.4 Summary of Jamaica's Current Energy Situation, and Moving Forward

The exorbitant cost to consumers and the economy as a whole of Jamaica's current import-dependent, petroleum-based electricity system necessitates greater energy conservation and a transition to more affordable, domestic renewable energy sources.

Both the uncertainty surrounding the feasibility of LNG plans and the significant time required for new coal capacity to come on line mean that these fossil fuel resources will not be able to contribute to Jamaica's energy diversification goals in the near term. Efficiency upgrades at Jamaica's existing power plants, as well as expansion of renewable energy capacity, should therefore be central in energy planning efforts. In particular, current plans to expand capacity at Wigton Windfarm and the Maggoty hydropower facility should be executed promptly. Additional capacity from a range of other renewable resources, including solar and biomass, should also be installed.

The following chapters examine the key opportunities for expanding efficiency measures and renewable energy capacity, as well as practical finance and policy recommendations for how to turn strong sustainable energy potential into real, on-the-ground projects.

* This cost was calculated based on the shipping costs of USD 3–4 per million Btu above the Henry Hub price of natural gas at export from the United States, plus an additional USD 1–2 per million Btu for regasification fees based on the expected LNG market size in the country.

2 | Energy Efficiency Potential

Key Findings

- Energy efficiency measures can result in significant cost savings over a short time frame, especially in Jamaica where high energy costs create many low-hanging-fruit options.
- Jamaica's petroleum power plants are highly inefficient; upgrades at existing plants can play an important role in reducing energy costs in the near to medium term.
- Jamaica's electricity grid has high transmission and distribution losses; strengthening grid infrastructure and reducing electricity theft can reduce grid-system inefficiencies.
- Major reductions in Jamaica's bauxite and alumina production—a sector with high energy consumption needs—played a significant role in reducing the country's energy intensity.
- Equipment efficiency standards and improved power generation efficiency at Jamaica's alumina refineries can have a big impact on reducing nationwide energy consumption, especially if plans to reopen the Alpart refinery move forward.
- The hotel and tourism industry has high potential for achieving energy savings due to high electricity costs from lighting and air conditioning, as well as available financial resources to implement improvements.
- Jamaican households have relatively low energy consumption, but high electricity costs still pose a burden. Appliance standards and building efficiency codes can keep energy costs down as Jamaica's economy grows.
- The National Water Commission (NWC), Jamaica's water and sanitation service provider, is the country's single largest electricity consumer and faces prohibitive energy costs. The NWC has several measures under way to reduce water losses and energy consumption.
- Financing barriers continue to hinder implementation of cost-saving efficiency measures. Financial options, capacity building needs, and policy reforms are examined in Chapters 7 and 8 of this Roadmap.

2.1 Background

Every country has a unique set of challenges and opportunities for undertaking a sustainable energy transformation. The energy structure and level of energy efficiency are determined by a broad range of factors, including past energy prices and policies, types of economic activity, overall electricity demand, and local knowledge and attitudes about energy conservation. In developing a Sustainable Energy Roadmap for a given area, identifying opportunities for efficiency improvements in the most energy-intensive sectors is an important initial step.

Energy efficiency measures are used to reduce the energy required to provide the same level of services for all economic sectors, including residential, commercial, and industrial. Employing energy efficiency technologies and practices in buildings, for example, provides the same level of comfort with a lower level of energy consumption.[1]

Improvements in energy efficiency are often the cheapest and fastest way to lessen the environmental and economic costs associated with an energy system. Energy efficiency is an important first step because of its compounding effects: when a user demands one less unit of energy because of efficiency measures, the system typically saves much more than one unit of energy because of avoided losses during generation, transmission, and distribution. Especially for Jamaica, where technical and non-technical grid losses are relatively high, end-user efficiency savings can translate into much greater savings in generation. Efficiency improvements also amplify the benefits of developing utility-scale renewable energy by increasing the impact of added renewable power capacity.

Energy efficiency measures also offer some of the most cost-effective tools for reducing carbon dioxide (CO_2) emissions. Especially in a country like Jamaica, which has high energy costs and relatively few efficiency measures currently in place, there are large gains to be made in this area. In many cases, energy efficiency measures actually save money because of reduced energy costs.

Until a few years ago, Jamaica's energy consumption per capita was relatively high for the region, due in large part to the high power demand of the bauxite and alumina sector. When this industry collapsed in Jamaica following the global economic crisis of 2008, the country's energy intensity decreased dramatically, resulting in a relatively low per capita electricity consumption, as well as GDP.[2] (See Figure 2.1.)

2.2 Defining Priority Sectors for Efficiency Measures

Economic sectors in Jamaica that should be targeted for energy efficiency measures and technologies are those that: 1) account for a large share of the country's energy consumption, 2) are highly energy intensive or inefficient, or 3) are central to the Jamaican economy. The sectors included in this analysis are: electricity generation, electricity transmission and distribution, bauxite and alumina, hotels and tourism, residential buildings, and the National Water Commission.

2.3 Electricity Generation

As seen in Chapter 1, much of Jamaica's power generation capacity is aging and inefficient. A 2007 study comparing the efficiency of different types of plants connected to the JPS grid found that the average efficiency for oil- and diesel-fired steam generation is low, at below 30%.[3] (See Table 2.1.) Hydropower plant efficiency* in Jamaica is also low, averaging around 75–80%, below the international norm of 80–85% for small hydro plants.[4]

Electricity is also dispatched inefficiently from Jamaica's various generation facilities. In 2002, JPS installed new combustion turbines at the Bogue plant that run on automotive diesel oil, one of the most expensive fuels for power generation and more costly than Jamaica's other main petroleum power fuel source, heavy

* Hydropower efficiency is determined by calculating the percentage of the river's potential energy that is converted into electricity.

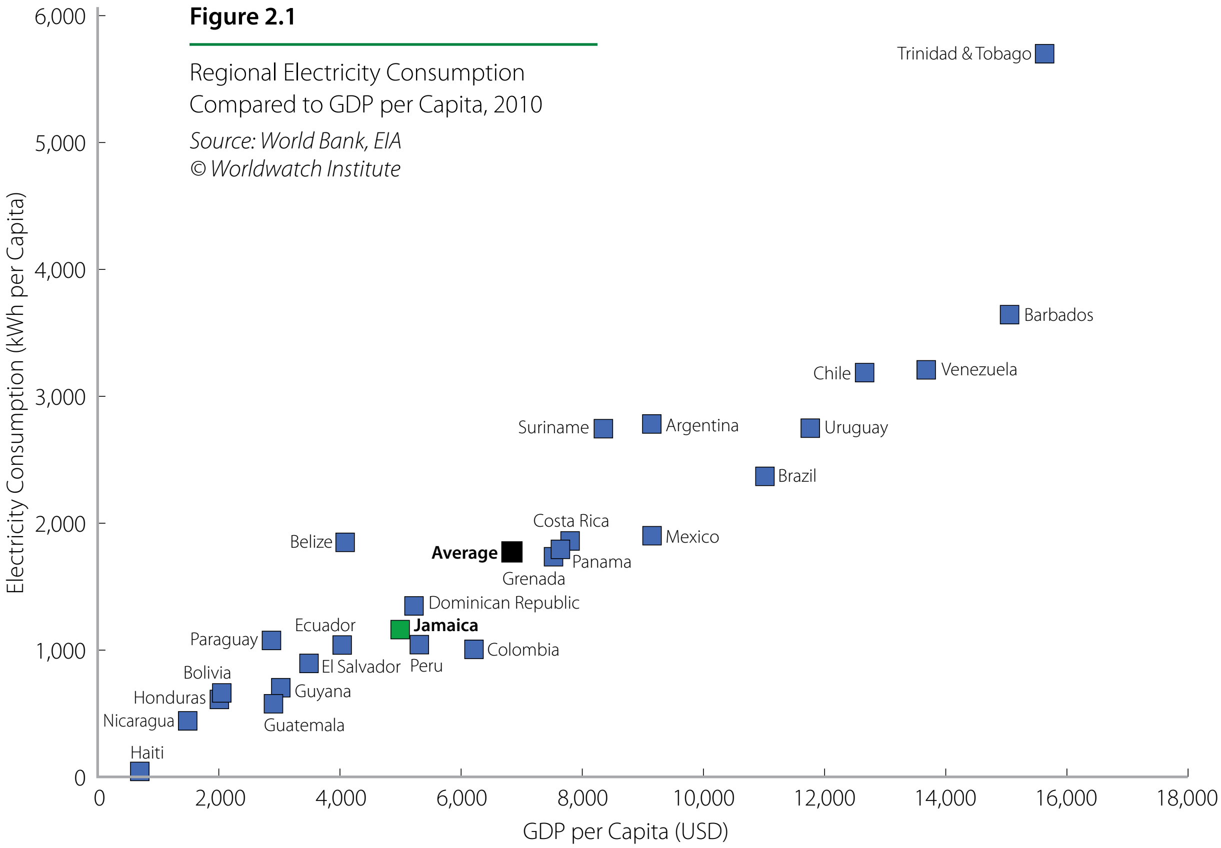

Figure 2.1

Regional Electricity Consumption Compared to GDP per Capita, 2010

Source: World Bank, EIA
© Worldwatch Institute

Table 2.1. Power Plant Efficiencies by Generation Technology and Owner (where applicable) in Jamaica

Generation Technology	Efficiency
	percent
Jamaica Private Power Company (JPPC) low-speed diesel	43.0
Jamaica Energy Partners (JEP) medium-speed diesel	41.9
Combined-cycle	40.7
JPS low-speed diesel	37.4
Oil-fired steam	26.8
Gas turbine	24.4

Source: See Endnote 3 for this chapter.

fuel oil. The turbines were planned for back-up power generation, but they have been used instead for baseload power since they were commissioned. The expense of diesel fuel means that running these turbines consistently for baseload power has increased electricity prices for Jamaican consumers.[5]

Even as Jamaica continues to explore different options for energy diversification, efficiency upgrades at its existing power plants are an important way to reduce energy costs in the near to medium term.

2.4 Electricity Transmission and Distribution

The JPS grid has high transmission and distribution losses, at 22.3% in 2011; this is down from a high of 24.7% in 2008 but is still significantly higher than the national target of 17.5%.[6] Yet even Jamaica's target share is high by international standards: in the United States, total transmission and distribution losses average only about 7% annually.[7]

About 10% of electricity losses in Jamaica are technical losses resulting from an inefficient and overburdened national grid system. Chapter 4 examines in more detail the need for grid strengthening and expansion, including replacement of existing transmission lines with higher-voltage lines to accommodate increasing power demand.

The vast majority of Jamaica's transmission and distribution losses are non-technical losses due to illegal connections and electricity theft.[8] A JPS study found that just over half of non-technical losses in 2010 were from nearly 140,000 illegal connections across 130 communities, with the average illegal connection drawing 180 kWh per month from the grid, or about 4% of electricity consumption that year.[9] The number of illegal connections is significant when compared to the JPS customer base of 589,030 consumers—of which 584,430 are residential or small commercial—and average monthly household electricity consumption of 173 kWh.[10] The remainder of non-technical losses was due to electricity theft or non-payment of bills by metered JPS customers.[11]

Both grid strengthening to reduce technical losses and anti-theft measures to reduce illegal connections and increase payment collection for electricity services are needed to improve the efficiency of Jamaica's electricity transmission and distribution system. These measures, as well as the regulatory and policy framework necessary to implement them, are examined in Chapters 4 and 8 of this Roadmap.

2.5 Bauxite and Alumina Sector

The bauxite and alumina mining and production sector is the third largest energy end-user in Jamaica, accounting for 18% of the country's petroleum consumption.[12] Jamaica is the fifth largest bauxite exporter in the world and has estimated bauxite reserves of 1.9 billion tons.[13]* Bauxite is the raw material for alumina production, and the majority (70%) of Jamaica's bauxite exports is refined into alumina while the remaining 30% is exported in raw form.[14]

Three of Jamaica's four alumina refinery plants closed in 2009 as a result of the global economic crisis, causing annual alumina production to fall by half from some 16 million tons to some 8 million tons.[15] The remaining Jamalco plant in Halse Hall, Clarendon, has a capacity of 1.4 million tons. In April 2013, MSTEM announced plans to reopen the 1.7 million ton Alpart refinery in Nain, St. Elizabeth, by 2016.[16]

Jamaica's alumina processing plants are among the least efficient in the world, due in part to the low alumina concentration of the country's bauxite resources. To produce one ton of aluminum, six tons

* All units of measure in this report are metric unless indicated otherwise.

of Jamaican bauxite are needed, compared to four tons in Guyana, another Caribbean country with significant bauxite reserves.[17] Combined with the low efficiency of power generation plants at Jamaica's refineries, the bauxite and alumina sector faces very high energy costs, a leading factor in the need to close the plants in 2009. Nevertheless, the country thus far has set no efficiency standards for bauxite mining and alumina production equipment.

Jamaica's alumina refineries have their own cogeneration facilities for some of their electricity and heating needs. These systems currently provide 138 MW of grid capacity (see Chapter 1), with efficiency of about 75–85%. MSTEM has announced a goal of increasing grid-connected generation capacity to 354 MW and improving cogeneration efficiency to more than 90%.[18]

The impending reopening of the Alpart plant highlights the need for refining and power generation efficiency improvements in Jamaica's bauxite and alumina sector. MSTEM has identified alumina refineries as a priority for accessing alternative fuel resources, including natural gas and coal, should Jamaica begin importing one of these fossil fuels on a significant scale. In the meantime, efficiency improvements to existing facilities can reduce energy costs without the uncertainty associated with natural gas supplies (see Chapter 1) or coal's pollution impacts.

2.6 Hotel and Tourism Industry

The hotel and tourism industry in Jamaica is energy intensive, due mostly to the requirements for lighting and air conditioning. Lighting accounts for about half of electricity consumption in Jamaican hotels, and heating, air conditioning, and ventilation (HVAC) account for over one-quarter.[19] Despite the high energy costs (energy expenses in some hotels in Jamaica account for as much as 10% of revenue), hotels have been slow to introduce energy efficiency measures, even though studies demonstrate that relatively small investments and practices can result in 20–30% energy savings.[20]

A 1997–2002 project of the U.S. Agency for International Development's Energy Audits for Sustainable Tourism initiative reduced nightly energy use per guest by 12% in participating hotels, cutting total energy consumption by more than 1.6 million kWh over the project period. The project resulted in efficiency savings of USD 616,555, following an investment of just USD 175,000—representing a more than 3.5-fold return.[21]

The Development Bank of Jamaica (DBJ) is financing ongoing energy efficiency and renewable energy pilot projects, including in two hotels: the Sunrise Club Hotel and Footprints on the Sands. Efficiency measures through these projects include energy management systems to shut off electricity use in unoccupied rooms and replacing old air conditioning systems with more-efficient inverter units.[22] (See Table 2.2.)

Given the comparatively strong financial resources of Jamaica's hotel and tourism industry, as well as its high energy costs, efficiency improvements should spread throughout the sector once pilot projects like those supported by DBJ demonstrate the significant savings that can be achieved even in the short term. Greater awareness of efficiency benefits and access to project financing will speed this transition.

Table 2.2. Energy Savings from Efficiency and Renewable Energy Projects in Hotel Pilot Projects

Hotel	Efficiency Measures	Total Project Cost	Project Annual Savings	Simple Payback Period
		J$	J$	years
Sunrise Club Hotel	Replace electric water heaters with solar water heaters; install a 12 kW grid-tied solar PV system	J$4,330,000	J$1,360,000	3.18
Footprints on the Sands	Install an energy management system; replace electric water heaters with solar water heaters; replace 21 standard air conditioning units with inverter units	J$6,473,350	J$1,500,000	4.32

Source: See Endnote 22 for this chapter.

2.7 Residential Sector

In 2011, JPS's 513,970 household electricity customers together consumed 1,064.5 GWh of power, or 33% of the electricity generated that year.[23] Between 2003 and 2011, the average monthly electricity consumption for Jamaican households dropped from 200 kWh to 173 kWh.[24] This drop was mostly a result of higher electricity prices related to rising oil costs, which peaked in 2008, as well as energy efficiency measures such as distribution programs for compact fluorescent light bulbs.

Electricity demand to power household appliances is also increasing rapidly in Jamaica. A comparison of the country's 1997 energy survey with the results of a 2006 survey of appliance use conducted by the Planning Institute of Jamaica (PIOJ) and the Statistical Institute of Jamaica demonstrates the rising share of households with electrical appliances including televisions, kitchen appliances, and washing machines.[25] (See Table 2.3.)

In addition to appliance standards, energy efficiency building codes can play an important role in reducing energy consumption not only for the residential sector but also for commercial and government buildings.

Table 2.3. Share of Households with Electrical Appliances, 1997 and 2006

Appliance	1997	2006
	percent	
Television	74.0	93.1
Refrigerator	69.6	82.0
Microwave oven	6.9	34.6
Washing machine	6.4	23.1
Electric stove	3.2	4.1
Electric water heater	2.9	6.4
Air conditioner	1.7	3.0

Source: See Endnote 25 for this chapter.

Recommendations for incorporating energy efficiency into Jamaica's building code are discussed in Chapter 8 of this Roadmap.

2.8 National Water Commission

The National Water Commission (NWC), Jamaica's water and sanitation service provider, is JPS's single largest customer, consuming 204.5 million kWh in 2009, or about 5% of the total electricity generated.[26] This reliance on JPS electricity leaves the NWC vulnerable to oil price shocks: in August 2008, NWC electricity costs peaked at over USD 7 million as a result of the global spike in oil prices.[27] Overall costs have fallen slightly since, to roughly USD 6.2 million per month in 2011, but they still account for nearly 40% of total NWC revenue, at USD 15.7 million.[28] NWC consumption accounts for about half of all government electricity costs, which approximated USD 13 million per month in 2012.[29]

The NWC has established an Energy Committee to develop recommendations to reduce energy consumption and costs and to review and update the Commission's current energy strategy. Already, the NWC has institutionalized many energy efficient practices, including mandating the selection of top-performing water pumps and other energy efficient equipment in the procurement process. The Commission is also pursuing rehabilitation of water storage reservoirs and pipeline networks to reduce water losses that near 70% from the point of production to end-user consumption.[30] Reducing water losses would enable the NWC to deliver the same services while producing less water, thereby requiring less electricity input.

The NWC has prioritized the eastern and western parts of the island, where energy costs are high, for rehabilitation efforts. The high population concentration in and around the capital city, Kingston, contributes to significant energy costs on the eastern side. The hilly topography on the western side of the island requires significant energy expenditures because of the need to lift water as high as 600 meters (2,000 feet) in some locations.[31]

In addition to reducing water losses, infrastructure strengthening will allow the NWC to reduce its use of energy-consuming equipment during JPS peak electricity demand hours (6 p.m. to 10 p.m.), further reducing electricity costs. Instead of consuming electricity to pump water, the NWC will make use of improved storage reservoirs to deliver water to customers during these times.

The NWC is also considering producing its own distributed power generation on-site at its facilities. The Commission has been approached by solar PV companies with proposals for generation facilities of up to 0.5 MW of capacity.[32] The NWC has demonstrated interest in pursuing these options if the financing proves beneficial, including through net billing or net metering programs. The NWC is also considering small hydro as a self-generation option.[33]

Rehabilitation efforts are financed in part through the "K factor fund," which functions as a loan fee added to customer bills for non-revenue water infrastructure rehabilitation, to be paid back at a later date.[34] Energy efficiency measures are also being funded by loans from MSTEM.[35]

2.9 Summary of Jamaica's Energy Efficiency Potential

Jamaica's high electricity costs mean that energy efficiency improvements can result in significant cost savings for the country, especially for large and energy-intense sectors. Improving power generation efficiency and reducing grid losses—both of which are far short of international standards—are a first step to reducing electricity prices for consumers.

End-use improvements and standards for key sectors can achieve significant additional energy savings. Even since its decline in 2009, the bauxite and alumina sector continues to be one of Jamaica's largest energy consumers. Plans to reopen the Alpart refinery highlight the need for equipment standards and improved power generation efficiency at these plants.

The hotel and tourism industry has some of most immediate opportunities for efficiency upgrades due to significant demonstrated cost savings. Building codes and appliance standards can further improve efficiency in this sector, in addition to reducing household energy consumption.

Jamaica's single largest electricity consumer, the National Water Commission, has seen the benefit of reducing energy costs and is currently implementing a wide range of measures to reduce water losses, conserve energy, and possibly even produce its own power.

Despite the economic motivation for energy efficiency improvements, lack of awareness of these benefits and upfront financing costs still pose a barrier to implementation. Chapter 7 of this Roadmap examines existing financing options and capacity building needs, and Chapter 8 recommends additional energy efficiency programs and standards.

3 | Renewable Energy Potential

Key Findings

- Jamaica has excellent renewable energy potential, especially for solar and wind energy; the entire island's electricity demand could be met with renewable resources.
- Jamaica has extremely strong solar energy potential across the entire island. Solar irradiance is relatively consistent throughout the year and is strong even in winter months.
- Distributed solar PV generation at the household and commercial levels can play an important role in Jamaica's energy mix.
- Several locations in Jamaica have extremely strong wind energy potential. Just 10 medium-sized wind farms could provide over half of the country's current power demand.
- Wind energy potential varies throughout the day and year, but several locations in Jamaica still have very high wind speeds even during relative lows.
- Developing additional small hydropower capacity can provide cheap power to Jamaica's electricity grid and energy access for remote locations.
- Improving the efficiency of Jamaica's current biomass generation facilities and connecting them to the grid could provide nearly 10% of the country's electricity demand with agricultural waste alone.
- A coherent national waste management strategy is necessary in order to harness the significant public and private interest in waste-to-energy development.

This chapter assesses Jamaica's physical renewable energy resources, specifically solar, wind, small hydro, biomass, waste-to-energy, wave and tidal, and geothermal. It also provides an overview of current renewable energy technologies that are applicable in Jamaica.

3.1 Building on Existing Assessments

Resource assessment data and maps at the national level provide a country with the necessary information to justify interest and further financing in that country's energy resources. However, higher-resolution assessments that focus on individual regions and cities are necessary for planning power generation and transmission expansions, although these assessments can be more expensive and time consuming to obtain.

This chapter provides national assessments of solar, wind, small hydro, biomass, waste-to-energy, wave and tidal, and geothermal resources in Jamaica, as well as more in-depth analysis of the solar and wind potentials in specific zones. To avoid duplicating other thorough and ongoing resource assessments that are being conducted with the support and interest of the Jamaican government, Worldwatch has collaborated with MSTEM and the institutions undertaking these assessments to present their results in this Roadmap and to integrate them into our broader recommendations for the country's electricity sector and policies.

Several past and ongoing studies have estimated renewable energy resource potential in Jamaica. (See Appendix II.) In February 2013, the Petroleum Corporation of Jamaica made all of its renewable resource assessments—including resource potential and financial feasibility data—publicly available on the state-owned company's website in order to provide useful information to private renewable energy developers.[1] These assessments provide an important overview of resource availability in the country, although most studies are not detailed enough or are too site-specific for the purposes of this Roadmap. In the cases where the studies are detailed and cover a broad expanse of Jamaica's geography, we have included the results to supplement our assessments or in lieu of conducting new assessments.

Worldwatch has consulted closely with stakeholders within the Jamaican government to determine priority areas for additional resource assessments. The solar zones examined in this Roadmap were carefully selected by MSTEM based on priority sites for distributed solar PV generation. The wind zones were chosen in consultation with Wigton Windfarm to provide resource information for sites not covered under their ongoing site-based assessment. Satellite-based solar and wind resource assessments are provided by 3TIER, a private renewable resource mapping company. (See Appendix I for 3TIER's complete reports.)

3.2 Solar Power Potential

3.2.1 Global Status of Solar Power

Today, a suite of relatively mature technologies is available to convert the sun's energy into electricity. These generally fit into one of two categories: photovoltaic (PV) modules that convert light directly into electricity, and concentrating solar thermal power (CSP) systems that convert sunlight into heat energy that is later used to drive an engine. Solar power can operate at any scale, but whereas CSP systems are considered viable generally only as utility-scale power plants, PV technology is modular and can be scaled for use on a household rooftop, in medium-size settings such as resorts and industrial facilities, or as part of a large network of utility-scale PV farms.

Traditionally, solar power has not been cost competitive with conventional electricity generation, due in part to the high level of direct and indirect subsidies benefiting fossil fuels.[2] Government support, whether in the form of feed-in tariffs, renewable portfolio standards, tax credits, or other mechanisms, has been necessary to help level the playing field and accelerate the adoption of solar technologies. But costs for solar systems are falling rapidly, and an oversupply of modules may further speed this decline. The price of crystalline silicon PV modules fell by 45% in only two years, dropping from USD 4.05 per watt in 2008 to USD 2.21 per watt in 2010.[3] Costs have since fallen even further, with module prices as low as USD 1.22 per watt.[4]

Until recently, CSP costs were lower than for solar PV; however, the dramatic reduction in PV costs over the past few years has made PV technology comparable or even cheaper than CSP. Nevertheless, further CSP cost reductions are expected as commercial deployment of the technology expands. More-efficient generation technologies and improved storage are expected to reduce CSP capital costs by up to 40% or more by 2020.[5]

In certain situations, solar is already cost competitive: PV installations in the Persian Gulf region, for example, are offsetting electricity generated from oil, bringing positive returns.[6] The 74% increase in new PV installations worldwide in 2011 alone—totaling 70 GW that year—is a result of both strong support policies and rapidly declining technology costs.[7]

3.2.2 Current Status of Solar Power in Jamaica

Jamaica currently has very limited installed solar energy capacity. The exact level of installed solar PV capacity is unknown but minor.[8] To date, solar PV has been used only for a few specific applications in the country, including rural electrification, street lighting, and some stand-alone generation. Jamaica Broilers, the largest poultry producer in the Caribbean, completed installation of 600 kW of solar PV panels across 40 of its chicken houses in 2013—one of the country's largest solar projects to date. (See Case Study 3 on page 121.)

3.2.3 Solar Power Potential

Jamaica shows tremendous solar potential. The global horizontal irradiance, or GHI (see Sidebar 1), ranges from 5 to 7 kWh per square meter per day (kWh/m^2/day) throughout most of the country. (See Figure 3.1.) Some parts of the country have an even higher GHI, reaching up to 8 kWh/m^2/day. To put things in perspective, Germany, which has nearly half of the world's installed solar PV capacity, has very few locations with a GHI above 3.5 kWh/m^2/day. Phoenix, Arizona—a city in the U.S. southwest famed for its solar potential—has an average GHI of 5.7 kWh/m^2/day.[9]

The only region of Jamaica that has a relatively low GHI (4–5 kWh/m^2/day) is in the east, just south of Port Antonio. This region has a very low population density, however, and its solar resource could still be used for off-grid generation. In general, Jamaica's direct normal irradiance (DNI) levels are low for commercial CSP development but are suitable for solar water heating.[10] (See Sidebar 2, page 40.) Additional research into Jamaica's CSP potential should be conducted, however, due to the technology's potential to provide large-scale, baseload energy using thermal energy storage systems.

Beyond producing nationwide solar resource maps, 3TIER performed more granular analysis for seven

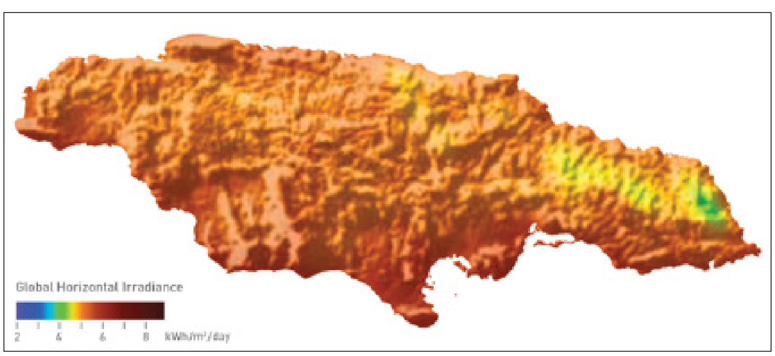

Figure 3.1

Average Global Horizontal Irradiance (GHI) in Jamaica

Source: 3TIER

Sidebar 1. Key Measurements of Irradiation and Their Application to Solar Resource Analysis

The solar assessment for Jamaica produced by 3TIER for Worldwatch includes three different measurements for solar irradiation: global horizontal irradiance (GHI), direct normal irradiance (DNI), and diffuse horizontal irradiance (DIF).

Measurement	Description	Application
GHI	Total solar radiation per unit area that is intercepted by a flat, horizontal surface	Solar PV installations
DNI	Total direct beam solar radiation per unit area that is intercepted by a flat surface that is at all times pointed in the direction of the sun	CSP installations and installations that track the position of the sun
DIF	Diffuse solar radiation per unit area that is intercepted by a flat, horizontal surface that is not subject to any shade or shadow and does not arrive on a direct path from the sun	Some PV installations that are best suited to diffuse radiation (DIF is included in the GHI calculation)

Based on the specific conditions of Jamaica's solar resource and the suitability of specific solar technologies, this assessment focuses mostly on the country's GHI measurements for solar PV installations and DNI for solar water heating applications.

For additional detail, see Appendix III.

zones: St. Ann's Bay Hospital, Montego Bay convention center, the Petroleum Corporation of Jamaica building, the Soapberry wastewater treatment plant, the Scientific Research Council building, the Trade Winds Citrus company site, and Wigton Windfarm. Each zone is 50 kilometers by 50 kilometers, centered on the identified location, and is split up into high-resolution grid points of approximately 1 kilometer by 1 kilometer. These assessments were conducted primarily to demonstrate the potential for decentralized solar PV systems at the sites; therefore, the resource analyses summarized below focus on GHI measurements.

The seven zones assessed in Jamaica have very strong solar resources by global standards. Even during the winter months at the weakest sites, the country's monthly average GHI exceeds that of Germany, the world leader in installed solar PV capacity.[11] (See Figure 3.2.) Although the resource peaks during

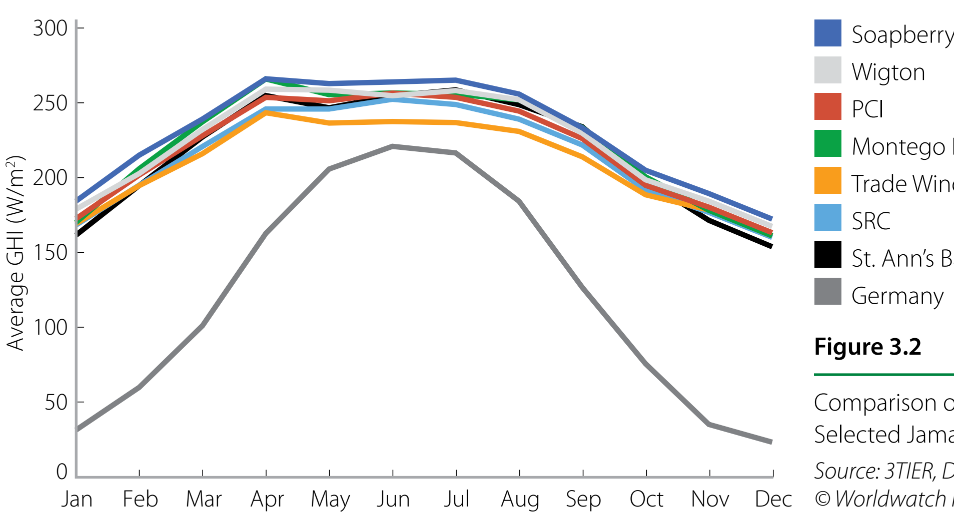

Figure 3.2

Comparison of Monthly Average GHI, Selected Jamaican Zones vs. Germany

Source: 3TIER, DWD
© Worldwatch Institute

the summer months in both countries, Jamaica's solar potential varies significantly less throughout the year. Monthly mean GHI varies across all zones throughout the year. It is highest from April to August, remains relatively high in March and September, and dips throughout the rest of the year.

During the course of the day, GHI peaks in the early afternoon throughout the year, typically highest between 10 a.m. and 3 p.m. and peaking between 12 noon and 1 p.m. The peak hourly mean in all zones is consistently more than three times the daily mean. The long-term annual mean GHI (1997–2012) for the seven zones ranges from 5.01 to 5.50 kWh/m^2/day (213.8 to 229.3 W/m^2); by comparison, the long-term annual mean GHI in Germany (1981–2010) is 2.88 kWh/m^2/day (120 W/m^2), just over half the level of Jamaica's zones.

Sidebar 2. Solar Water Heating in Jamaica

In addition to providing electricity, solar energy is commonly used for heating water and spaces, replacing electric or gas systems. Solar hot water systems are broadly cost competitive globally, with payback periods under two years in many cases. By the end of 2011, global solar water and space heating capacity reached 232 gigawatts-thermal. More than half of this was in China, and the vast majority is used for water heating.

In small-island states, the attractiveness of solar water heating is clear. Cyprus is the world's leader in installations per capita, and Barbados's experience is considered a Caribbean renewable energy success story. Duty-free equipment imports and tax incentives in the country have created a thriving market, with 40,000 solar hot water systems installed on homes, businesses, and hotels as of 2008, and a market penetration of 33% for residential buildings. The success of this project was cited explicitly by the Inter-American Development Bank in announcing a multimillion dollar loan to Barbados for continued renewable energy development.

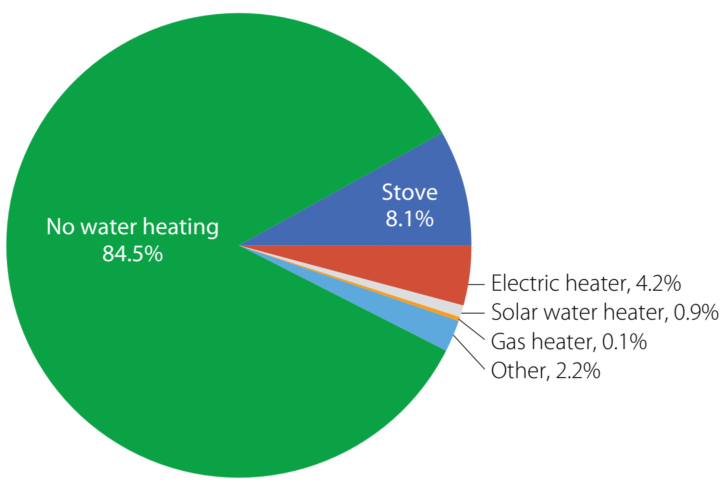

Figure 3.3

Share of Jamaican Households with Water Heating Systems in 2006, by Type

Source: PIOJ

As of 2010, Jamaica had 20,000 solar water heating systems installed out of approximately 525,000 households in the country, up from just 7,000 systems in 2005. The majority of households do not have any type of water heating system (see Figure 3.3), and therefore a share of the remaining households might not create demand for additional solar hot water. The market for water heating is growing, however: between 1997 and 2006, the share of households with electric water heaters grew from 2.9% to 4.2%, contributing to increased demand load peaks on the JPS grid. In 2005, the company Solar Dynamics estimated that 3–4 square meter solar collector systems could meet hot water needs in these households and save a total of 75,000–100,000 MWh annually..

Jamaica's DNI levels (the most suitable measurement of solar potential for solar hot water systems) are well suited for widespread adoption of the technology. Success stories in other small-island countries, particularly Barbados, demonstrate the benefits of developing a solar water heating market in Jamaica.

For the complete 3TIER site assessments of DNI resources, see Appendix I.

3.2.4 Summary of Solar Power Potential

All seven study sites have strong solar potential, but there are other sites in Jamaica that boast even higher GHI levels, above 7 kWh/m^2/day. A majority of Jamaica's territory appears to have an average GHI of at least 5 kWh/m^2/day, signaling that solar PV could be an electrification solution for decentralized generation and rural communities. (For details on the effects of wind and temperature on solar PV power production, see Appendix IV.)

All seven study sites appear capable of supporting PV generation at any scale from residential to utility-scale, although they are not ideal for CSP development. If one square kilometer of solar PV panels were installed at each of the sites, these systems could provide nearly a quarter of Jamaica's current power demand. (See Table 3.1.)

Wigton Windfarm, in particular, could be a strong candidate for utility-scale PV development due to the site's existing transmission infrastructure and to the low losses related to wind and temperature. Variability of the solar resource from year to year could affect the feasibility of utility-scale solar PV but should not pose a problem for residential or small commercial capacity.

The study sites also appear suitable for solar water heating and residential and commercial solar PV installations. During the summer months, the solar potential peaks for all study sites.

Table 3.1. Average Annual Solar Generation Potential in Jamaica Zones

Site	Annual Generation per 175 Watt Module*	Annual Generation for Three Modules	Annual Generation per Square Kilometer†	Share of 2011 Generation from One Square Kilometer of PV Modules
	kilowatt-hours		gigawatt-hours	percent
St. Ann's Bay Hospital	362	1,086	131	3.2
Montego Bay Convention Centre	373	1,119	135	3.3
PCJ Building	364	1,092	132	3.2
Soapberry Wastewater Treatment Plant	379	1,137	138	3.3
Scientific Research Council Building	354	1,062	128	3.1
Trade Winds Citrus project	341	1,023	124	3.0
Wigton Windfarm	388	1,164	141	3.4
Total	**N/A**	**N/A**	**929**	**22.4**

** Includes effects of wind and temperature.*
† Assumes that energy production per square kilometer is cut in half to account for maintenance, prevention of shading, and construction of other equipment.

Based on the 2011 average Jamaican residential customer's annual electricity consumption of 2,071 kWh (as reported by JPS), and the average solar potential from the seven zones summarized in Table 3.1, a one-square-kilometer solar PV farm in Jamaica could power more than 64,000 households.

Aside from the seven study sites, there are other avenues for solar development that deserve closer scrutiny. In locations in the southern half of the country with strong solar resources, either PV or even CSP utility-scale solar development may be viable. Opportunities also exist for off-grid solar development, particularly to increase electricity access in remote parts of Jamaica that are not currently connected to the national grid.

3.3 Wind Power Potential

3.3.1 Global Status of Wind Power

Outside of hydropower, wind has been by far the most successful renewable electricity source, with 238 GW of wind power installed globally by the end of 2011.[12] In some markets, the costs of wind power are estimated at 4–7 U.S. cents per kWh in attractive locations, making it fully competitive with fossil fuel technologies.[13] Although turbines come in many sizes, wind power is used mostly for centralized utility-scale generation, but innovations for smaller-scale generation make decentralized wind power an increasingly viable option. Small-scale (50–100 kW) wind-diesel hybrid systems are growing in the Caribbean, and a U.S.-funded project in Dominica is aimed at demonstrating the viability of wind generation facilities under 250 kW in the region.[14]

Wind turbines can provide on-site electricity generation for large electricity consumers such as a factory or a farm. Unlike traditional on-site thermal generators, however, wind is intermittent and cannot be started up at will. Connecting these turbines to the grid can significantly increase the value of the electricity, as landowners are able to sell excess power.

3.3.2 Current Status of Wind Power in Jamaica

Jamaica currently has two commercial-scale wind farms operating: Wigton Windfarm and Munro Wind Farm. Munro, owned by JPS, is located in St. Elizabeth and is a four-turbine facility with 3 MW of capacity.

The Wigton site, located on the Manchester Plateau, was chosen for its strong resource, with wind speeds averaging 8.3 meters per second (m/s) over a six-year period.[15] Phase I of the facility was commissioned in 2004 with an initial capacity of 20.7 MW, and consists of 23 turbines with 900 kW each of capacity and 49-meter hub heights.[*16] Phase II, comprising nine 2 MW Vestas V80 wind turbines with 67-meter hub heights, began exporting electricity to the grid in December 2010 and contributed an additional 18 MW of capacity.[17] Since the start of operations in 2004, Phase I generated between 44.2 and 59.4 GWh per year; the Phase II expansion approximately doubled this.[18] (See Table 3.2.)

3.3.3 Wind Power Potential

Wind resources in the Caribbean region benefit from trade winds, the year-round steady winds that come into the region from the northeast. The winds tend to be reliable all year, but strengthen in the winter.

* Hub height refers to the height of the wind turbine. Wind speeds are typically faster at higher hub heights.

Table 3.2. Wigton Windfarm Sales to JPS, 2004–2012

	Wigton Phase I		Wigton Phase II	
Year	Electricity Sales to JPS Grid	Capacity Factor	Electricity Sales to JPS Grid	Capacity Factor
	kilowatt-hours	percent	kilowatt-hours	percent
2004/2005	44,206,037	26.1	—	—
2005/2006	51,433,650	28.4	—	—
2006/2007	55,734,200	30.6	—	—
2007/2008	53,216,800	29.4	—	—
2008/2009	45,930,100	25.3	—	—
2009/2010	59,407,631	32.6	—	—
2010/2011	50,661,203	27.9	11,976,593*	—
2011/2012	46,368,604	25.5	44,717,351	28.3

** Wigton Phase II became operational in December 2010 and sold electricity to the grid for about three months until March 2011, the end of fiscal year 2010/2011.*
Source: See Endnote 18 for this chapter.

Beginning in 1995, the Petroleum Corporation of Jamaica conducted wind speed assessments to identify suitable sites for wind generation facilities. These assessments led to the selection of Wigton for a 20 MW wind farm (which has since been expanded to 38.7 MW). Through these assessments, PCJ determined that at least three additional sites have wind resources suitable for 20 MW wind farms, and that Jamaica's strongest wind potential lies along the southern coast.[19] Green Castle (St. Mary), Blenheim (Manchester), and Spur Tree (Manchester), in particular, had high average annual wind speeds, at 7.2, 7.3, and 7.7 m/s respectively, at a height of 40 meters. The Wigton site in Manchester had the highest average wind speed at 8.3 m/s.[20]

With funding from the Inter-American Development Bank (IDB), Wigton Windfarm Ltd. is currently conducting wind assessments at 20 sites. Because these results will provide current and detailed wind resource data from across the country, Worldwatch is collaborating with Wigton to obtain the most up-to-date results from this assessment. Both these results and the 3TIER wind assessment are presented and analyzed in this Roadmap.

The IDB-funded Wigton wind assessment is using a total of 70 anemometers to take measurements at heights of between 10 and 60 meters.[21] (See Figure 3.4.) These measurements are then used to project the wind speeds at 80 meters, a common height for wind turbines. The project aims to estimate the wind potential for regions of Jamaica rather than the energy potential for specific sites. Land ownership of strong wind sites will be a key issue in the assessment's final summary of wind potential in the country.

The preliminary results of the Wigton assessment provide average wind speed projections over the six months from October 2011 to April 2012 at 18 sites.[22] (See Table 3.3.) Several of these sites compare favorably to the existing Wigton Windfarm.[23]

In addition to the ongoing anemometer assessments, Worldwatch contracted 3TIER to conduct zonal wind analyses at three additional sites selected in consultation with Wigton: Portland Parish,

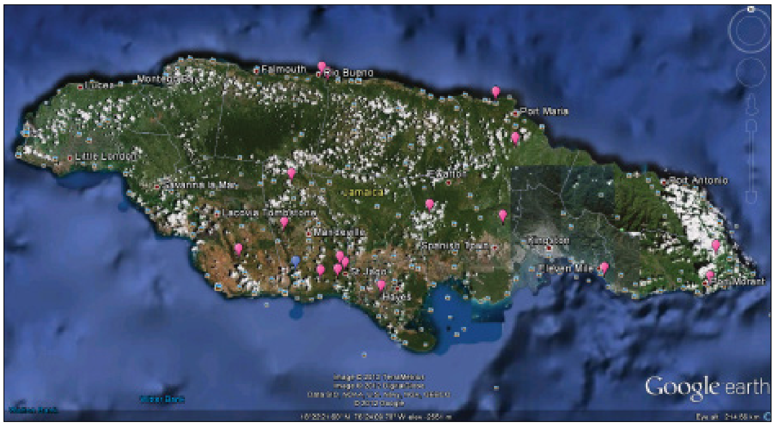

Figure 3.4

Wind Anemometer Measurement Sites
Source: Wigton Windfarm

Table 3.3. Preliminary Average Wind Speeds by Site, Wigton Assessment

Station	Projected Average Wind Speed at 80 Meters
	meters per second
Winchester	**9.7**
Rose Hill	**8.5**
Top Lincoln	**8.3**
Kemps Hill	**8.2**
Fair Mountain	**7.6**
Rio Bueno	7.5
Juan de Bolas	7.0
Ibernia	6.8
Bowden	6.7
Pratville	6.7
Bengal	6.2
Mt. Oliphant	5.8
Groove Town	**5.3**
Oracabessa	**5.2**
Mount Dawson	**5.0**
Highgate	**4.8**
Albion	**4.6**
Victoria Town	**4.2**

Note: Sites in green have a particularly strong wind resource to support utility-scale wind farm development. Sites in bold have slow average wind speeds with low potential for wind farm development. Wigton is considering relocating the equipment from these sites to take measurements at other potential sites.
Source: See Endnote 22 for this chapter.

Retrieve, and offshore. (See Figure 3.5.) (For detail on 3TIER's zonal wind assessment methodology, see Appendix V.)

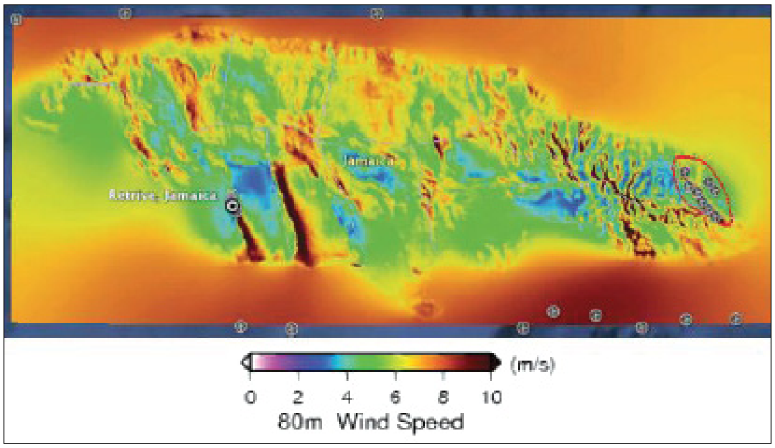

Figure 3.5

Wind Speed Map of Jamaica at 80 Meters

Source: 3Tier

Portland Parish (circled in red in Figure 3.5) is located on Jamaica's northeast coast and is home to the parish capital of Port Antonio as well as to the Blue Mountain ridge. Agriculture and tourism are Portland's main economic activities, with potential to expand ecotourism in the parish. Portland Parish is located in the path of the northeast trade winds, resulting in an extremely strong wind resource.

Retrieve is located in Jamaica's second largest parish, St. Elizabeth, on the country's southwest coast. Bauxite mining, sugar farming and refining, and tourism are the main economic activities, with ecotourism expanding in recent years. The Retrieve site is in a mountainous area, contributing to its strong wind potential.

To calculate offshore wind potential, the assessment used data collected from 11 disperse locations around the island (see markers in Figure 3.5). Jamaica's average offshore wind potential is strong, and more consistent than the country's onshore wind resources.

The 3TIER assessments suggest that all three surveyed zones have strong potential for wind power development. (See Table 3.4.) The average capacity factors range from 50% (mean wind speed of 8.60 m/s) to 59.6% (mean wind speed of 9.76 m/s), well above the 30% minimum value that is often used to determine if a site is suitable for commercial wind development. The wind speeds in these three zones

Table 3.4. Zonal Wind Speeds and Capacity Factors in Jamaica

Zone	Average Wind Speed at 80 Meters	Average Gross Capacity Factor at 80 Meters
	meters per second	percent
Portland Parish	9.76	59.6
Retrieve	8.60	50.0
Offshore	8.41	53.2

also compare favorably to the strongest sites identified in Wigton's preliminary assessment, summarized in Table 3.3.

Wind resources in each zone were measured by averaging measurements at multiple points. In Portland Parish, the average wind speed at the eight points assessed ranged from 6.28 m/s to 13.38 m/s; despite this wide range, seven of the eight sites would still be commercially viable for a wind farm, with capacity factors above 30%. For Retrieve, the average wind speed at the eight points assessed ranged from 7.62 m/s to 9.65 m/s, and here too even the site with the lowest average wind speeds would still be commercially viable (capacity factor above 40%) for a wind farm.

Although Jamaica has strong offshore wind resources, there are comparable and even stronger wind resources onshore that would likely be easier and more cost effective to develop. Of the 11 offshore locations assessed, certain points had stronger-than-average wind speeds; however, wind speed variation between offshore points was smaller than in each of the onshore zones.

Wind strength follows a fairly consistent seasonal cycle across all three zones, peaking from November to February and again in June and July, with yearly low (though still viable) speeds in September. (See Figure 3.6.)

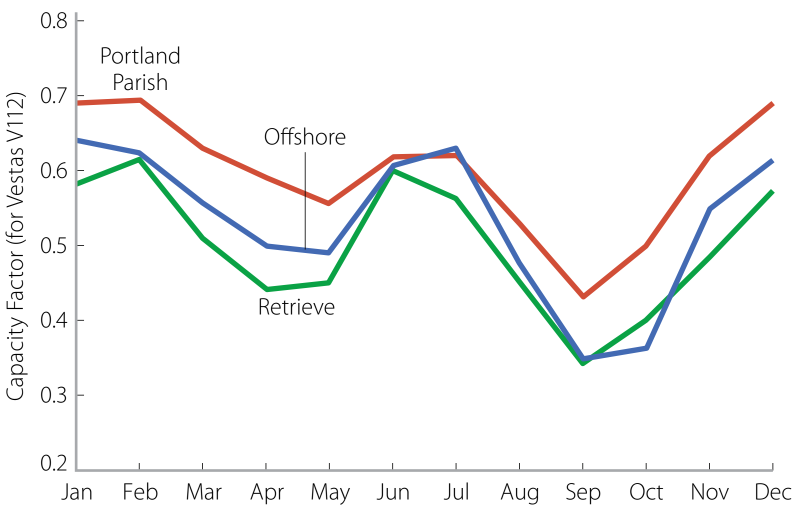

Figure 3.6

Seasonal Variability of Wind Zone Capacity Factors at 80 Meters

Source: 3TIER

Average wind strength also varies throughout the day, especially in the onshore wind zones of Portland Parish and Retrieve. (See Figure 3.7.) Retrieve's resource has a sharp peak between 2 p.m. and 5 p.m., while Portland wind strength has a somewhat smoother daily cycle, peaking between 9 a.m. and 5 p.m.

3.3.4 Summary of Wind Power Potential

Jamaica overall has very strong wind potential, and several regions demonstrate resource potentials that are suitable for wind energy development. Fifteen locations in the Wigton and 3TIER assessments had average wind speeds above 6 m/s. Assuming that 10 of these sites are developed, they could supply at least half of Jamaica's current power demand. (See Table 3.5.)

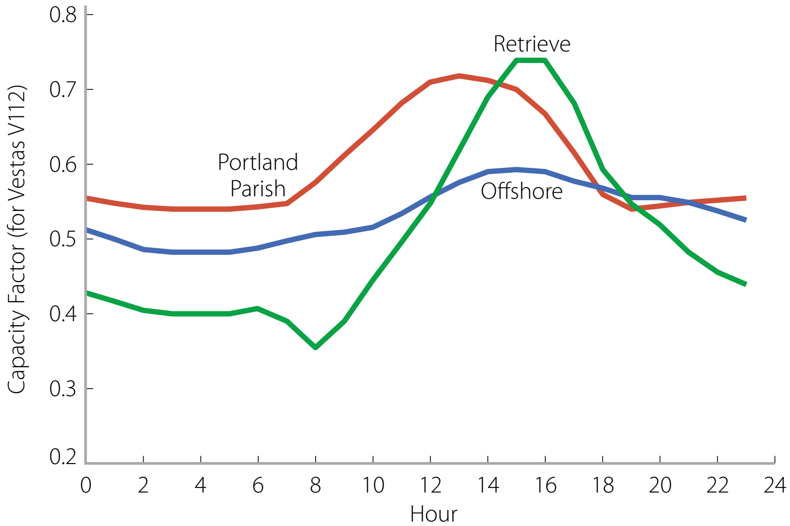

Figure 3.7

Daily Variability of Wind Zone Capacity Factors at 80 Meters

Source: 3TIER

Table 3.5. Annual Wind Generation Potential in Jamaica Zones

Site	Average Net Capacity Factor*	Average Annual Generation per 3 MW Turbine	Annual Generation per Square Kilometer†	Share of 2011 Generation from One-Square-Kilometer (60 MW) Wind Farm	Number of Wind Farms Needed to Meet Total 2011 Generation
	percent	gigawatt-hours		percent	
Portland Parish	50.6	13.3	266	6.4	16
Retrieve	42.5	11.2	223	5.4	19
Offshore	45.2	11.9	238	5.7	18

** Assumes estimated 15% loss to account for wake (slowed wind speed due to interruption from other turbines), electrical losses, etc.*
† Assumes 20 wind turbines in a one-square-kilometer area.

The area around the Retrieve site is well developed, suggesting that installation costs could be lower due to existing road and other infrastructure. Despite the strong resource in Portland Parish, the lack of infrastructure development there could make wind turbine installation in the area prohibitively expensive. Small-scale decentralized wind generation could provide an alternative for wind development in this zone. Exposure to tropical storms in Portland Parish and offshore also limits the viability of these sites for wind development.

Wind potential shows variability across the country, with most of the zonal assessments demonstrating a peaking resource in the afternoon and evening, which corresponds well to periods of peak energy demand in Jamaica. Wind potential also shows seasonal peaks during the summer and winter months, which could help to meet cooling needs during the slightly warmer season.

The three 3TIER study sites showed an average assessed capacity factor at or above 50%, far above the 30% level deemed suitable for wind energy development. Portland and Retrieve both show exceptional potential, each with an average gross capacity factor at or above 50%.

Of the 18 sites assessed by Wigton, five—Fair Mountain, Kemps Hill, Rose Hill, Top Lincoln, and Winchester—have the strongest resources, with average wind speeds ranging from 7.6 to 9.7 m/s. Ideally, the complete anemometer assessments of all sites (due for release in the second half of 2013) will provide detailed data of daily and seasonal resource variability, as well as longer-term average capacity factors. These measurements, as well as information about grid proximity and site viability, will help project developers choose the strongest locations for wind farm development.

3.4 Hydropower Potential

3.4.1 Global Status of Hydropower Technology

Large hydropower comprises the majority of global renewable power generation and accounts for about 16% of the world's electricity production.[24] But despite being a low-carbon, renewable energy source, large hydro often has serious environmental and socioeconomic impacts, including widespread ecosystem disruption and occasional large-scale displacement of populations.[25] China's controversial 20 GW Three Gorges Dam, for example, forced the relocation of 1.3 million local residents and has resulted in significant erosion and landslide dangers.[26] Because of the many potential downsides of large hydro, this report focuses primarily on small-scale hydropower development, which has fewer negative human and ecological impacts.

Small hydropower is used around the world, especially in remote areas, and can be an important renewable energy resource for providing power to communities that lack access to national electricity grids. Usually classified as hydropower that generates less than 10 MW of electricity, it can operate as "run-of-river" systems that divert water to channels leading to a waterwheel or turbine, or, similar to larger hydropower stations, it can operate as dammed systems that have small-scale storage reservoirs.

Small hydro has several advantages as an energy source, including the ability to provide cheap and clean electricity to communities that may not have access to other energy resources. Small hydropower requires certain site characteristics, including adequate stream flow and ensuring that users are close to the harvested hydro resource, which can limit its overall potential. Low consumer demand for the electricity due to the lack of economically productive uses for power in many rural areas often makes attracting financing difficult. Issuing grants or setting up preferential financing schemes, as well as cultivating local small hydro manufacturing economies, have proven crucial for initiating and maintaining small hydro projects.

3.4.2 Current Status of Hydropower in Jamaica

Eight run-of-river small hydropower facilities are currently in operation in Jamaica, all owned by JPS. (See Table 3.6.) Several additional facilities are in the planning stages. Construction of a 6.3 MW expansion to the 6 MW JPS Maggotty Hydropower Plant in St. Elizabeth was scheduled to begin in September 2011 and is expected to be completed by December 2013.[27] In addition, several 1–8 MW plants are scheduled to bring an additional 20 MW of small hydro on line along Jamaica's northern coast by December 2015. The project is currently awaiting investors but will be privately financed and supported by MSTEM and PCJ.

3.4.3 Small Hydropower Potential

The United Nations Economic Commission for Latin America and the Caribbean conducted assessments to determine the hydropower potential at 11 sites across Jamaica, with most sites demonstrating a potential

Table 3.6. Existing Small Hydropower Plants in Jamaica

Location	Capacity	Year of Commission
	megawatts	
Maggoty (St. Elizabeth)	6.0	1959
Lower White River (St. Ann)	4.8	1952
Roaring River (St. Ann)	4.1	1949
Upper White River (St. Ann)	3.2	1945
Rio Bueno A (Trelawny)	2.5	1966
Rio Bueno B (Trelawny)	1.1	1988
Constant Spring (St. Andrew)	0.8	1989
Rams Horn (St. Andrew)	0.6	1989

capacity of 2.5 MW or more, for a total of 33.4 MW.[28] (See Table 3.7.) Access to more detailed information from this assessment is necessary to determine the hydropower technologies appropriate for the sites identified—especially whether they are intended for run-of-river projects or small hydro dams. Up-to-date feasibility studies should also be conducted to assess the cost effectiveness of developing small hydropower capacity, including information regarding grid proximity or viability for off-grid development.

The Water Resources Authority of Jamaica has stream gauges that provide daily stream flow data at 100 sites. Only limited additional measurements are therefore required to determine potential for small hydropower facilities at additional sites.[29]

Table 3.7. Small Hydropower Potential at Various Sites in Jamaica

Location	Potential Capacity
	megawatts
Great River	8.0
Martha Brae River	4.8
Back Rio Grande	3.9
Rio Grande	3.6
Yallahs River	2.6
Spanish River	2.5
Wild Cane River	2.5
Morgan's River	2.3
Green River	1.4
Negro River	1.0
Dry River	0.8
Total	**33.4**

Source: See Endnote 28 for this chapter.

3.4.4 Summary of Small Hydropower Potential

Jamaica has several sites where small hydropower capacity could be developed. Although 33.4 MW is not a large share of Jamaica's nearly 1,000 MW of current power capacity, the country's small hydro resources can still play an important role in providing low-cost electricity to the electricity grid, as well as expanding energy access to remote locations.

3.5 Biomass Power Potential

3.5.1 Global Status of Biomass Power Technology

Energy can be generated from a wide variety of biological materials, including agricultural crop residues, forestry wastes (woody biomass), and even municipal solid waste. Electricity generation from biomass sources has the advantage of providing reliable baseload renewable power and can offset some of the intermittency of wind and solar generation in an integrated electricity system.

In most agricultural locations, crop residue follows a regular pattern of production and can be measured proportionally to the amount of land used to grow the crop and the number of times the crop is produced each year. Both crop residue and woody biomass can be used for heat or electricity, or they can be gasified to have the same functionality as oil and natural gas, but with lower net carbon emissions. Many potential sources of biomass feedstock exist in the Caribbean, including agricultural crop residues such as sugarcane bagasse, coffee husk, rice straw, and coconut shells, as well as woody biomass.

A key barrier to developing biomass as an energy source is the logistical challenge of collecting the dispersed biomass residue in an economically efficient way. In addition, the diversion of crop residues for energy purposes has the potential to compromise soil quality for future agricultural production by removing a source of soil nutrients. Proper agricultural waste management is thus important to achieving a net positive societal outcome from using biomass.

Scaling up biomass production also can have serious implications for the local environment, affecting key ecosystem services, biodiversity, and the tourism industry. Large-scale production of energy crops can encourage monoculture agricultural practices that cause a host of local environmental problems including soil degradation, loss of biodiversity, overuse of chemical pesticides and fertilizers, and contamination of waterways. Expanded use of biomass energy can also create competition with food crops for limited agricultural land, a trend that in some places has driven up food prices and placed a particular burden on poorer populations.[30]

Given the sizeable role that biomass energy may play in the future energy matrix, however, this resource cannot go overlooked. In the short-to-medium term, biomass generation can serve as a reliable, renewable source of baseload power, particularly as solutions are still being developed to address the variability challenges that arise with other renewable energy sources such as wind and solar.

Like biomass energy, bio-based fuels (biofuels) can be used for power generation as well, although they are most commonly used in the transportation sector. In particular, biodiesel derived from oilseed crops, such as the jatropha bush, can be used as a substitute for diesel to fuel thermal power plants. The use of biofuels for electricity generation is not suitable for communities that are less reliant on petroleum-based fuels, however. It is also important to consider the wider impacts of biofuel production, which can be similar to those of biomass production—such as the effect on local food prices.

One way to assess biomass resources is to model the potentials for cultivating crops in particular locations, looking at environmental variables such as annual rainfall, soil nutrient levels, and average temperatures, as well as variables like land availability and economic costs. Although resource potentials vary depending on the location and crop considered, they are relatively easy to assess assuming that the data are readily available. It is harder, although equally important, to measure the secondary impacts of biomass development, such as the effects on food production. Assessing the potential of municipal solid waste is generally easy in areas that have waste collection and storage programs and that maintain data on waste levels.

3.5.2 Current Status of Biomass Power in Jamaica

Sugarcane bagasse is currently the main source of biomass fuel in Jamaica, with sugarcane processors using the cane residue to generate power at their own facilities. Sugar production in Jamaica has been in decline since its peak in 1965, and a significant amount of the 46,000 hectares of land designated for growing sugar cane is unused.[31] Jamaica currently produces some 1.5 million tons of sugarcane per year on 32,000 hectares of cropland, with a production rate of 53 tons per hectare.[32]

The Ministry of Agriculture (MOA) plans to greatly increase sugarcane production over the next few years, to reach an annual target of 3.5 million tons of sugar cane produced by both estates and private producers by 2016–17. The MOA plans to meet this production goal by expanding sugarcane production to 44,000 hectares and increasing production intensity to some 80 tons per hectare. Of this increased production, 1 million tons is expected to go toward ethanol for fuel blending (Jamaica currently imports ethanol) and rum production. The remaining sugar cane will be used to produce 200,000 tons of sugar per year, of which 80,000–90,000 tons will be for domestic consumers, and the rest exported to other Caribbean countries and elsewhere.

Jamaica currently has seven sugarcane processing factories with a combined capacity of over 4 million tons per year.[33] (See Table 3.8.) The Sugar Company of Jamaica, a government-run company, recently divested itself of its sugar factory holdings. The Trelawny and St. Thomas factories were sold to local investors in 2009, and the Frome, Monymusk, and Bernard Lodge factories were sold to COMPLANT, a Chinese company, in 2011.[34]

Existing bagasse cogeneration capacity in Jamaica is intentionally inefficient in order to dispose of the maximum amount of bagasse through burning, because at the time that the generation plants were built, excess electricity could not be sold to the grid.* Boilers were therefore designed to have efficiencies of less than 50%, even though efficiencies of close to 90% are feasible.[35] If bagasse generation is connected to the grid for sale of excess electricity, efficient high-pressure boilers can generate 110 kWh or more per ton of sugarcane. If efficient sugar processing and generation technologies are implemented in all Jamaican sugar factories, bagasse could feed 220 GWh of electricity into the Jamaican grid each 185-day harvest season (December through April).[†36]

* The cogeneration plants at Appleton and Worthy Park are exceptions, as they are equipped with efficient facilities.
† Based on 2003 sugarcane production.

Table 3.8. Sugarcane Factory Capacities in Jamaica

Factory	Rated Capacity	Daily Production
	metric tons of cane	
Frome*	1,080,000	6,000
Monymusk*	780,000	4,333
Bernard Lodge*	600,000	3,333
Trelawny*	360,000	2,000
St. Thomas*	300,000	1,667
Appleton	600,000	3,333
Worthy Park	312,000	1,733
Total	**4,032,000**	**22,400**

** Formerly owned by the Sugar Company of Jamaica.*

Several of Jamaica's sugar refineries have plans to expand their electricity generation, including a planned new cogeneration facility at Monymusk that will be supplied with bagasse from both Monymusk and Frome.[37] Discussions are currently under way regarding what fuel will be used for the facility in the harvest off-season. Options under consideration include coal, as well as alternative biomass crops such as switchgrass.[38] This plant is expected to be connected to the national electricity grid.[39]

Expanding sugarcane production to previous high levels through production of sugarcane ethanol would boost annual generation potential to 300 GWh, from 68 MW of capacity, without expanding agricultural land or competing with food crops.[40]

Plans for another bagasse cogeneration facility are in place to utilize surplus bagasse at Golden Grove. In contrast to the anticipated Monymusk plant, Golden Grove will seek to expand sugarcane production in order to generate power from bagasse year-round.[41] Due to environmental factors, the cane produced at Golden Grove is higher in fiber content compared to cane produced elsewhere on the island, making it ideal for bagasse generation.[42] Golden Grove is currently in discussions with JPS, MSTEM, and OUR to determine a suitable tariff rate to incentivize electricity sales to the grid.[43]

Jamaica also has 350 biodigesters for animal waste that produce an equivalent of 10,000 cubic meters of biogas, and 200 biodigester septic tanks for domestic sewage that produce an equivalent of 2,000 cubic meters of biogas.[44]

3.5.3 Biomass Power Potential

At the request of Jamaica's MSTEM, the biomass assessment presented in this Roadmap is based on a 2011 European Union-sponsored study conducted by Landell Mills Development Consultants Ltd. (LML), which analyzes the sugar industry's ability to export electricity to the national grid. The study examines the existing self-generation and cogeneration capacity of the sugar industry and provides recommendations on how to increase electricity generation and sales. The assessment focuses on bagasse generation potential because sugar cane is one of Jamaica's major crops and is currently the main source of biomass generation. Because of land use and food price competition concerns, the assessment is limited to agricultural waste rather than the production of dedicated fuel crops.

The LML assessment used the current estimated sugarcane crop of 1.8 million tons of cane, down from a high of 3.5 million tons during the 1970s. Given the MOA's plans to increase production to its previous high level, bagasse generation potential in the coming years could be greater than estimated.

Efficiency improvements are necessary to make sugar factories electricity self-sufficient before they can feed power to the grid. The average energy consumption for Jamaica's sugar mills, 22 kWh per ton of cane, is within the international standard of 20–25 kWh per ton but does not include additional fuel oil and diesel consumption. The average steam demand is 0.7 tons per ton of cane, greater than the international standard of 0.5 tons or below, resulting in low-power generation efficiency.

In addition to operational constraints, the generation units currently used in the mills are not well suited for electricity exports to the grid. Most of the mills' generating units operate at low pressure with low-efficiency turbines. With current policies and technology in place, electricity exports would result in negative profits for all but one of the six mills. The exception is the Appleton mill, which already has invested in a higher-pressure boiler.

Higher-pressure boilers and more-efficient equipment would allow the mills to generate more electricity out of one unit of steam (and more steam from one unit of bagasse), making cogeneration more economical. The use of higher-pressure boilers would enable greater electricity capacity and generation at the same current rate of sugarcane production due to higher efficiencies. The LML study examined three boiler pressure technology options: 20 bar, 40 bar, and 80 bar. (See Table 3.9.)

Table 3.9. Bagasse Generation Efficiencies, Capacity, and Generation Potentials

Pressure	Efficiency	Average Exports to Grid	Potential Additional Capacity
bar	percent	kilowatt-hours per ton of cane	megawatts
20	9.19	minimal	35
40	13.53	40	52
80	22.55	90	86

According to the LML study, existing boiler technologies and proper management of sugar mill generators could produce 140 kWh per ton of cane. With energy demand of 20–25 kWh per ton, sugar mills would be able to sell 120 kWh per ton to the grid.[45]

Even assuming high-pressure boilers and more-efficient condensing turbines, only four mills showed profits under Jamaica's current feed-in tariff rates. Even these projected profits are, for the most part, marginal and not enough to encourage investors. Again, Appleton mill is the only mill to show encouraging projected profits due to the lower initial investment required for its boiler.[46]

Regardless of improvements in technology, LML found that any improvements to the functionality of the sugar mills' powerhouses would require the construction of completely new power sections for each mill. The age and state of current infrastructure makes it unsuitable for upgrade or refurbishment.

The sugarcane harvest season in Jamaica lasts about 185 days, meaning either that sugar mill generation will be limited to that time frame or that alternative biomass fuels will need to be used during the rest of the year. The LML study calculated the annual amount of additional biomass necessary for each sugar mill to operate sugarcane generation facilities year-round. (See Table 3.10.)

Table 3.10. Biomass Needs for Year-round Sugarcane Facility Generation

Sugar Mill	Biomass
	tons per year
Appleton	94,200
Frome	93,300
Monymusk	50,700
Worthy Park	34,400
Golden Grove	29,700
Everglades	16,500

Other agricultural wastes, such as coffee pulp and coconut husks, also contain fibrous materials that could potentially be used for power generation. Waste materials such as these require special handling and transport, however, and no large volumes of supply are currently located near existing biomass plants. At present, Jamaica does not have plantations dedicated to growing energy crops. The use of dedicated energy crops as a biomass feedstock would require the establishment of a new industry, as well as careful assessment of its environmental and food-price impacts.

The LML study estimated electricity generation figures for bagasse and other biomass at all six sugar mills, based on the three different boiler pressures. (See Table 3.11.) Improving bagasse generation facilities to the highest modeled efficiency and operating year-round with additional biomass fuels could provide nearly 10% of Jamaica's current electricity demand.

Alternatively, if sugar mill generation is limited to bagasse, a share of the bagasse could be pelleted and stored for use as fuel during the non-harvest season to achieve the bagasse-only generation levels listed in Table 3.11. Because this generation would be spread out over the course of an entire year, the capacity additions would be smaller than those listed in Table 3.9. If sugarcane production increases from the current 1.5 million tons to 3.5 million tons per year by 2016–17, bagasse generation alone could provide close to 9% of Jamaica's electricity demand without other biomass sources.

3.5.4 Summary of Biomass Power Potential

By improving power generation efficiency at Jamaica's existing sugar refineries and using waste from current agricultural production, biomass can provide nearly 10% of the country's current electricity demand. This approach reduces many of the environmental and food-price impacts typically associated with biomass generation by avoiding growing crops dedicated specifically to power production.

Table 3.11. Bagasse and Biomass Electricity Generation Potentials

	Bagasse Only			Combined Operation (Bagasse and Supplemental Biomass)		
Location	**20 bar**	**40 bar**	**80 bar**	**20 bar**	**40 bar**	**80 bar**
			megawatt-hours			
Frome	0	22,066	50,880	30,974	67,665	126,854
Appleton	5,995	15,682	33,408	37,261	61,712	110,102
Monymusk	0	10,288	27,556	16,815	35,042	68,800
Worthy Park	2,782	7,851	17,636	14,207	24,670	45,659
Golden Grove	0	4,336	13,483	9,867	18,862	37,684
Everglades	0	4,045	8,577	5,481	12,113	22,021
Total	8,777	64,267	151,540	114,604	220,063	411,119
			percent			
Share of National Demand	**0.2%**	**1.6%**	**3.7%**	**2.8%**	**5.3%**	**9.9%**

In order to provide adequate incentive for sugar producers to improve generation efficiencies and sell excess power to the grid, payments for independent bagasse power generation need to be increased.

3.6 Waste-to-Energy Potential

3.6.1 Global Status of Waste-to-Energy Technology

Municipal solid waste (MSW) can be used for electricity generation. This waste contains significant organic material, and, when burned, it can drive a turbine similar to any other thermal power plant. In addition, landfill gas (primarily methane) can be captured and used to power a thermal power plant. MSW is advantageous because it can be used as a baseload source of power. Because the waste would otherwise be discarded, it can also be a cheap fuel source that requires little resource extraction or change in land use.

3.6.2 Current Status of Waste-to-Energy in Jamaica

Jamaica generates about 1.5 million tons of waste annually, of which 55% is collected by garbage trucks.[47] Of the waste collected, 69% consists of organic matter.[48] Jamaica's waste stream produces relatively high amounts of methane due to its high organic matter and moisture content. These characteristics also make the current waste stream somewhat unsuitable for direct combustion for waste-to-energy, as waste with high moisture content does not burn efficiently. The Planning Institute of Jamaica estimates that the country's MSW generation will increase to 2.4 million tons by 2030, although effective waste management programs could lower this level to 1.8 million tons.[49]

There are currently no utility-scale waste-to-energy electricity generation facilities in Jamaica. MSTEM recently abandoned plans to construct two waste-to-energy direct combustion plants with a combined generation capacity of 65 MW (about 500 GWh of generation annually) at the Riverton dump in

Kingston.[50] Together, the facilities would have converted more than 750,000 tons of waste per year, more than half of Jamaica's annual waste generation.[51]

The financing, construction, and operation of the combined 65 MW plants were to have been undertaken by PCJ through a joint venture with Miami-based Cambridge Project Development Company Inc. The project would have relied on loans to cover 80% of capital costs. The plants were scheduled to begin commercial operation in 2012 and to run for 20 years; however, the Cambridge Project Development consortium for the facility has since gone bankrupt.[52]

The lack of a coherent plan for waste management in Jamaica is also stalling development of waste-to-energy generation in the country. The National Solid Waste Management Authority (NSWMA) has failed to develop a strategy, creating uncertainty among potential waste-to-energy developers about whether and how they would be able to access the waste stream.[53]

3.6.3 Waste-to-Energy Potential

The waste-to-energy assessment for this Roadmap is based on several existing studies, as well as original calculations. It draws from Renewable Energy and Energy Efficiency Department (REEED) and MSTEM feasibility assessments for waste-to-energy incineration facilities, waste-to-energy incineration generation plans from a private company, data regarding Jamaica's waste content and collection for biogas potential, and an assessment of sewage energy potential by the Scientific Research Council.

MSTEM and REEED completed waste availability and feasibility assessments for direct combustion waste-to-energy facilities at Jamaica's largest waste disposal sites. These assessments were intended to support construction of the two waste-to-energy power plants at the Riverton site that have since been abandoned. The results of the original assessment are presented and analyzed below, alongside the potential for capturing biogas electricity generation from landfills as well as sewage waste treatment. The Jamaican government also has assembled a waste-to-energy task force to explore other options.

Direct Combustion

Although past studies of MSW incineration have found that direct combustion is not generally profitable, it was until recently the centerpiece of Jamaica's waste-to-energy plan, including the National Waste-to-Energy Policy. MSTEM estimates that one ton of MSW would generate 500–600 kWh of electricity via direct combustion.

REEED conducted an economic viability analysis for a 300-ton-per-day MSW facility at Riverton City with capital costs of USD 25–30 per ton and annual operating costs of USD 80–100 per ton.[54] The analysis determined that this level of waste incineration would add 9 MW of power to the grid with a thermal efficiency of 25% to produce 67.5 GWh of electricity per year. REEED calculated that the net annual profit of this facility would be USD 4.71 million.[55] (See Table 3.12.)

A joint venture led by the company Naanovo also conducted a feasibility assessment for a 21 MW waste-to-energy facility (three 7 MW individual plants) in Jamaica. The assessment determined that using high-efficiency technology, the facility could process 540 tons of waste per day, about one-third of the waste stream volume at Riverton. At an efficiency of 48%, this plant would produce 178 GWh per year.[56]

Table 3.12. Economic Viability Analysis for Waste-to-Energy Facility

Annual waste to be incinerated	109,500 tons per year
Annual operating cost	USD 11.63 million
Annual energy sales to the grid (at USD 0.1205 per kWh)	USD 8.13 million
Annual tipping fee (at USD 75 per ton)	USD 8.21 million
Net profit	USD 4.71 million

Landfill Biogas

Electricity generation from biogas produced in landfills can be a cleaner way to generate waste-to-energy power, given sufficient waste volume and high moisture and organic content in the waste stream.

To determine the viability of landfill gas generation in Jamaica, calculations of projected gas flow are necessary. Landfill gas flow of 1,000 cubic meters per hour for at least 20 years is the typical minimum level for a cost-competitive electricity generation facility.[57] The largest of Jamaica's nine waste disposal sites is Riverton, which receives about 380,000 tons of waste each year.[58]

In landfill conditions, each ton of waste with 60% organic matter will produce 180 cubic meters of methane over 50 to 100 years, 50–80% of which can be captured through vertical gas extraction wells and horizontal drains to be used for heat and electricity cogeneration.[59] Landfill gas has about half the heating value of pipeline-grade natural gas.[60]

Based on these figures, biogas electricity production and cogeneration are viable at the Riverton site. Using the conservative 60% organic matter and 50% methane capture estimates, the current annual waste stream at Riverton could provide 3,904 cubic meters of methane flow for electricity or cogeneration, well above the 1,000 cubic meter minimum level for cost-competitive generation. (See Figure 3.8.)

Despite the apparent viability of biogas generation based on these initial calculations, electricity generation from waste is highly dependent on the country's waste management strategy. Because Jamaica's waste authority NSWMA is promoting plans to increase composting in the country, the organic and moisture content of the waste stream at Riverton could be reduced, making it unviable for biogas generation. Clarity on NSWMA plans is essential before waste-to-energy planning can take place.

- 380,000 tons per year x 100 years = 38 million tons
- 38 million tons x 180 cubic meters methane per ton over 100 years / 100 years = 68.4 million cubic meters of methane per year
- 68.4 million cubic meters of methane per year / 8,760 hours per year = 7,808 cubic meters of methane per hour
- 7,808 cubic meters of methane per hour x 50% capture rate = 3,904 cubic meters of methane flow per hour for electricity or cogeneration

Figure 3.8

Biogas Flow Calculation for Riverton

Furthermore, the calculation in Figure 3.8 is only a rough, preliminary estimate. More-detailed assessments are needed to determine the true potential of biogas waste-to-energy for Jamaica.

Sewage Biogas

Jamaica's sewage waste has additional electricity generation potential. Biogas from the sewage treatment process can be harnessed to generate enough on-site electricity to meet treatment plant energy requirements—a significant accomplishment considering that the National Water Commission is Jamaica's single largest energy consumer.[61] (See Chapter 2.)

Currently, 70% of Jamaica's sewage goes untreated, and the remaining 30% of domestic wastewater that does pass through the central sewage system is only minimally treated and released into the open sea or land with high organic loads.[62] Most of Jamaica's approximately 150 sewage treatment facilities were constructed in the 1960s and are in poor condition, with less than half functioning properly.[63]

A proposal by Jamaica's Scientific Research Council found that collecting and treating domestic sewage under anaerobic conditions at the country's central wastewater disposal site in Kingston could deliver 840–6,300 MWh of surplus electricity to the grid. The range in potential generation depends on the wastewater collection rate.[64]

3.6.4 Summary of Waste-to-Energy Potential

There is significant interest in waste-to-energy power generation in Jamaica from both the government and private energy developers, and MSW and sewage waste could be harnessed to supply a small share of the country's energy demand. Viable waste-to-energy plans cannot be developed, however, until the NSWMA develops a comprehensive waste management strategy so that energy developers can know the volume, characteristics, and cost of accessing waste fuel. Straightforward guidelines for co-locating waste-to-energy plants at landfills, clear roles regarding landfill management and waste collection and sorting, and viable tipping fees for waste loads are needed in order for developers to invest in waste-to-energy facilities.

Furthermore, the health and environmental impacts of direct incineration waste-to-energy generation without stringent emission control systems should be strongly considered in determining which waste-to-energy systems to develop on Jamaica's major landfills.

3.7 Alternative Renewable Energy Technologies

In addition to the mainstream renewable energy technologies discussed above—for which Jamaica has significant available resources—two additional options are worth exploring briefly: wave and tidal energy, and geothermal energy.

Wave and tidal energy can have significant potential, especially in island countries like Jamaica; however, technology costs remain too high for commercial-scale development. Geothermal, meanwhile, is a mature technology that can provide a significant share of power generation in countries with strong resources. It appears unlikely that Jamaica has strong enough geothermal potential to develop electricity capacity; however, geothermal heating and cooling systems, which do not have the same site-specific resource requirements, could be implemented.

3.7.1 Wave and Tidal Energy

Wave energy is a third-hand form of solar energy and a second-hand form of wind energy. Sunlight warms pockets of air, producing temperature gradients that induce atmospheric circulation in the form of wind, which then drives water to produce waves. The peaks and troughs that store the wave's potential energy are proportional to how fast and consistent the wind blows over an open area of water.

Tidal energy, in contrast, is created by imbalances between the gravitational forces of the Earth, Moon, and Sun in orbit and the forces required to keep the orbits in place. The regular cycles of the orbits create a regular cycle of inflows and outflows in certain tidal estuaries and channels. Many tidal power systems use a design similar to wind turbines, except the units are located underwater at the base of tidal estuaries and channels. Because water is roughly 1,000 times denser than air, the systems are capable of producing roughly 1,000 times more energy than wind using water moving with the same flow speed as the air. Tidal energy resource assessments are based on grid-based oceanographic data including maximum current velocities, seabed depth, maximum probable wave height, seabed slope, significant wave height, and distance from land.[65]

It is important to note that, unlike most of the other renewable energy technologies examined in this chapter, marine energy technologies are far from commercially viable and still have prohibitively high costs. Wave and tidal power face similar economic and technical barriers. The costs of building and installing these systems, including both the generation equipment and the underwater cables, is extremely high, and existing global capacity is almost exclusively in the form of pilot and demonstration projects. There also are many factors that need to be considered when developing marine energy projects, including corrosion of equipment in seawater, coexistence with other human uses of coastal waters such as fishing and recreation, grid connection obstacles, and potentially significant ecosystem disturbances.

Despite the current barriers, wave and tidal power may soon play an important role in some locations, such as small-island states that have extensive coastal territories. As technologies mature and costs come down, wave and tidal generation could become cost competitive in the long term in some coastal regions.[66] Ocean thermal energy conversion for power generation and sea water air conditioning systems are additional marine energy technologies that deserve further research, as they could provide future power and thermal energy to Jamaica.[67]

Jamaica currently has no existing wave or tidal facilities. A Global Environment Facility (GEF) project administered by MSTEM and REEED commenced in January 2011 with the aim of providing wave-generated electricity to one or two small coastal communities.[68] The project has since been abandoned due to violation of the JPS license that was in force at the time.

3.7.2 Geothermal Energy

Geothermal energy, or thermal energy stored in the Earth, can be used to generate electricity or to provide heating and cooling services. Currently, geothermal plays a limited role in the electricity sector worldwide, with only 11 GW installed in 24 countries.[69] The main limitation is the need for reservoirs with very high temperatures near the Earth's surface. The Geysers in California, the world's largest geothermal power plant, takes advantage of 300-degree Celsius steam less than two kilometers below the surface.[70] Such resources are rare, however, and most deep geothermal reservoirs are technologically or economically unfeasible to exploit.

Nevertheless, good geothermal resources can contribute significantly to a region's electricity portfolio.

For example, geothermal accounts for 27% of electricity generation in the Philippines and 4.5% in California.[71] A major advantage of geothermal power compared to many other renewable sources is that it can be used as a baseload source of energy.

The most common use of geothermal energy is for heating and cooling. Because geothermal heating and cooling systems rely on reservoirs with much lower temperatures, they are not as site specific and can be built around the world; at least 78 countries use geothermal energy directly for heating.[72] In addition to direct heating, geothermal resources can power heat pumps.

There are no country-specific geothermal resource assessments for Jamaica, and the country currently has no installed geothermal capacity. Regional geothermal resource assessments show low potential for the island of Hispaniola and some potential for Jamaica (around 100 MW), although this figure is widely considered a significant overestimate. The greatest geothermal potential in the Caribbean is found on the islands of the Lesser Antilles. To date, however, only Guadeloupe has installed geothermal capacity (4.5 MW).

Because Jamaica does not have high geothermal power potential, geothermal heating and cooling makes the most sense. Besides providing cooling in a very warm tropical climate, geothermal heating and cooling systems could also provide humidity control. Pipes would need to be placed only a few meters below the ground, making geothermal an applicable technology for government and commercial buildings and hotels.

3.8 Summary of Renewable Energy Potential

Jamaica has very strong renewable energy potential spread across the island and can meet almost all of its power demand with the resources assessed in this chapter. (See Figure 3.9.) Wind farms and distributed solar PV generation are especially viable and should be central in the country's energy mix. Preliminary estimates based on the detailed resource assessments conducted above show that installing one square kilometer of solar PV capacity at each of the seven sites examined, and building medium-sized (60 MW) wind farms at the 10 most favorable wind locations, could provide three-quarters of Jamaica's current electricity demand.

In addition, small hydro, biomass, and waste-to-energy can each play a limited but important role in powering the island. Improving the efficiency of existing biomass capacity can provide almost 10% of Jamaica's power demand using only agricultural wastes, thereby limiting negative environmental impacts. Small hydro capacity additions can be especially useful for expanding energy access to remote locations. Finally, Jamaica needs to develop a long-term waste management strategy in order to efficiently harness waste-to-energy potential.

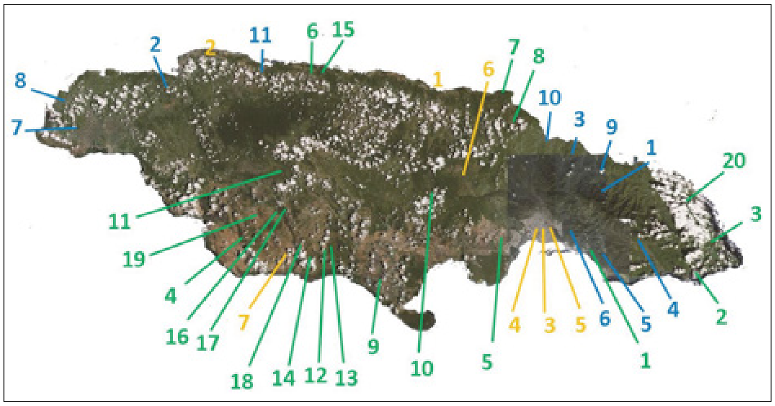

Figure 3.9

Renewable Energy Site Assessments in Jamaica

Map data: Google, Worldwatch Institute

Solar Sites (yellow)

1. St Ann's Bay Hosptal
2. Montego Bay Convention Centre
3. PCJ Building
4. Soapberry Wastewater Treatment Plant
5. SRC Building
6. Trade Winds Citrus Project
7. Wigton Windfarm

Hydropower Sites (blue)

1. Back Rio Grande
2. Great River
3. Spanish River
4. Negro River
5. Yallahs River
6. Wild Cane River
7. Morgan's River
8. Green River
9. Rio Grande
10. Dry River
11. Martha Brae River

Wind Sites (green)

1. Albion
2. Bowden
3. Winchester
4. Fair Mountain
5. Mount Dawson
6. Rio Bueno
7. Oracabessa
8. Highgate
9. Kemps Hill
10. Juan de Bolas
11. Ibernia
12. Pratville
13. Mount Oliphant
14. Groove Town
15. Bengal
16. Victoria Town
17. Top Lincoln
18. Rose Hill
19. Retrieve
20. John Crow Mountains

4 | Grid Improvement and Energy Storage

Key Findings

- Jamaica's electricity grid will require upgrades and expansion to accommodate growing energy demand, regardless of whether these needs are met with fossil fuels or renewable resources.
- Distributed generation, especially from household and commercial-scale rooftop solar PV systems, can reduce power system inefficiency by avoiding grid losses.
- The cost of grid connection for solar, wind, and small hydro installations will likely be minimal and should not pose a barrier to renewable energy development.
- Challenges associated with renewable energy variability can be minimized by upgrading the grid system infrastructure with higher-voltage transmission lines and improving operations and forecasting.
- Jamaica's existing diesel and fuel oil power plants can be quickly fired up and down in response to fluctuations in solar and wind generation; the current system is well suited to renewable energy integration.
- Integrating multiple renewable energy sources across a broad geographic area can further reduce renewable intermittency issues; in particular, combining solar and wind capacity on the grid can smooth out seasonal variability.
- Electricity storage options, especially batteries and pumped-hydro systems, can be paired with renewable energy capacity to store power produced during periods of high production and low demand, to be fed into the grid at peak hours.
- If the necessary grid-strengthening measures are implemented, renewable energy can reliably meet over 90% of Jamaica's electricity demand while lowering energy costs.

As examined in Chapter 3, Jamaica has very strong renewable energy resources that can generate enough electricity to meet the country's growing power demand. However, successfully integrating new renewable power generation into the national electricity system requires a strong, functioning grid. The World Bank is currently preparing a detailed assessment of Jamaica's electricity grid that should provide good insight into the technical and operational improvements needed to accommodate increasing power generation and integrate distributed and variable renewable energy, as well as estimated costs for these measures. In the meantime, this chapter gives an overview of Jamaica's current electricity grid, as well as proven solutions for strengthening the system to handle new renewable capacity.

4.1 Overview of Jamaica's Existing Grid

JPS owns about 14,000 kilometers of transmission and distribution lines that make up the national electricity grid. This includes 400 kilometers of 138 kilovolt (kV) lines and almost 800 kilometers of 69 kV lines. The company has twelve 138/69 kV interbus transformers with a total capacity of 798 megavolt amperes (MVA), as well as 54 substation transformers with a total capacity of 1,026 MVA that transmit power from transmission lines to Jamaica's 24 kV, 13.8 kV, and 12 kV distribution lines.[1] (See Figure 4.1.)

Figure 4.1

Jamaica Electricity Grid

Source: JPS

As of 2008, the length of the distribution network in Jamaica had remained unchanged at 14,000 kilometers since 2001 (when JPS was privatized), in comparison to most other countries in the Latin America and Caribbean region, which have added new power lines.[2] This is likely due to the long-term JPS monopoly on transmission and distribution in Jamaica, which reduces the incentive for the company to incur expansion costs. (See Chapter 8 for grid regulatory recommendations.)

According to the Planning Institute of Jamaica, the rate of transmission and distribution losses in Jamaica's electricity system worsened from 17.6% in 1998 to 24.7% in 2009.[3] JPS statistics vary slightly, with a peak of 24.7 percent occurring in 2008 before dropping to 23.3 percent in 2009.[4] Electricity theft, which is responsible for more than half of grid losses, occurs most commonly in urban areas like Kingston, Spanish Town, Montego Bay, and Mandeville.[5] (See Chapter 1.)

Jamaica also has one of the highest rates of both duration and frequency of electricity service interruptions in the Latin America and Caribbean region, with 27 interruptions totaling 50 hours of outages in 2008.[6] The JPS availability factor was 84% and the forced outage factor was 8% in 2010.[7] In 2010, OUR examined Jamaica's electricity system and determined that due to demand growth, rates of forced outages, and maintenance needs of generating units, grid reliability could at times be compromised.[8]

Although the grid provides electricity access to 98% of Jamaican households, there is still a need to strengthen and expand the grid, especially to accommodate decentralized and/or variable generation from renewable sources.[9] The management challenges for electricity transmission and distribution on the grid are unique for decentralized and centralized generation. This chapter examines the challenges and solutions available for expanding grid capacity and flexibility to integrate a greater share of renewables into the national electricity supply.

4.2 Decentralized/Distributed Generation

Distributed generation typically refers to electricity generation produced at the site of consumption. The scale of distributed generation can range from a few kW in residential installations to tens of MW for large industrial generation. As examined in Chapter 3, distributed renewable energy generation, particularly from solar PV systems at the residential to commercial scale, can play an important role in reducing Jamaica's energy costs and fossil fuel import dependence.

The relatively high technical and non-technical losses in Jamaica's transmission and distribution grids, estimated at 22.3%, have a significant positive impact on the economics of distributed generation systems. Because these systems generate electricity at the point of use that does not need to pass through the grid, a kilowatt-hour that comes from a rooftop solar panel is more valuable than a kilowatt-hour from a coal or diesel plant, equivalent to 1.3 kWh from a power plant given the current grid loss rate. Integration with the grid under a net metering or feed-in tariff regime, however, would mean that some of the distributed generation system's output would then be subject to the grid's losses.

Jamaica's grid losses are reflected in high electricity prices, which make distributed systems more financially attractive in Jamaica than in countries where grid power prices are lower. The installation of distributed generation systems would also reduce the number of overall kilowatt-hours that have to be generated in the country, improving the efficiency of the electricity system. Consequently, the promotion of distributed generation is a worthy national priority.

Integrating large amounts of distributed capacity onto the grid requires that both grid operators and regulators have a strong understanding of the technical issues (and solutions) associated with distributed generation, from power flow reversal to unintentional islanding.[10] (See Sidebar 3.)

Sidebar 3. Technical Challenges and Solutions Associated with Distributed Generation

Power flow reversal. In instances where high distributed power generation exceeds the local electricity demand, this increases the voltage in the local network and may exceed the voltage that the grid supplies, reversing power flow. Reversed power flow may overload and damage electrical equipment if the grid is already experiencing power flow near its maximum capacity. To design a system that effectively addresses power flow reversal and maximum power flow parameters, engineers must first identify the unique infrastructure of the grid and distributed generation for each new large installation—as well as on a localized aggregate basis if there is a high density of small distributed generation installations.

Voltage regulation. Voltage regulation allows grid operators to ensure a high quality of electricity by maintaining distribution line voltage to within 5–10% of the designed operating voltage. Distributed generation systems fluctuate in voltage output during operation, or when turned on and off, and can potentially harm sensitive loads (like manufacturing equipment) to which they supply power. Static VAR compensators (a specialized electrical device for high-voltage systems) and load tap changers (mechanisms contained within power transformers) can regulate voltage levels by incrementally adjusting power on the distribution line.

Harmonic distortion. When the fundamental frequency of the electric current is distorted by other interfering frequencies, this can cause the total effective current to exceed the capacity of the transmission system, leading to overheating and voltage regulation problems. Any distributed generation unit connected to the grid must comply with limits for maximum harmonic distortion as outlined by the Institute of Electrical and Electronics Engineers (IEEE) Standard 519. Modern inverters are able to reduce the distortion effect of distributed generation to the point of negligibility. Passive and active power filters are electronic devices that can also suppress harmonics.

Protection scheme disturbance. This may occur when an existing network has several measures in place to protect against bidirectional power flow or an exceeding of the maximum transmission line capacity. When a new distributed generation system begins feeding power back into the grid, a fuse (for example) may melt if the power flow exceeds a certain threshold to prevent damage to the grid downstream. Fuses, circuit breakers, relays, reclosers, and sectionalizers may all need to be redesigned.

Unintentional islanding. This is the most significant problem that may occur with distributed generation systems, although it has been largely solved by advances in inverter standards. In the event of a grid outage, breakers automatically isolate the section of the grid in which a power interruption occurs. A generator that is still providing power within this "island" during a grid interruption can interfere with the breaker isolation procedure, leading to longer-than-necessary outages. More seriously, a technician attempting to fix a line that is thought to be disconnected but is actually still being powered can create a lethal hazard. Furthermore, if a generator is operating within an island, the alternating current (AC) on the island may begin to alternate out of phase with the AC on the grid, and out-of-phase reconnection can severely damage equipment.

Both passive and active solutions exist for preventing islanding by disconnecting the distributed generation within a standard time frame. Passive methods measure the grid power at the distributed generation unit's point of connection and disconnect the unit if the grid power ceases, but they are designed to be insensitive in order to prevent unnecessary disconnection. Active methods solve the islanding issue by periodically injecting small bursts of power into the grid and observing the response, but they are criticized for reducing power quality.

Source: See Endnote 10 for this chapter.

Global smart-grid innovations also can be implemented in Jamaica to deal with challenges to distributed generation. In particular, smart-grid systems can quickly and effectively communicate data from distributed generation systems, enabling the utility to respond to fluctuations in power output to meet demand.

It is difficult to determine the exact level of penetration of distributed generation that will require strengthening of Jamaica's distribution network. It is critical, however, that distributed generation installers and grid operators devote serious attention to these issues. Utility engineers should also plan for future penetration of distributed generation when completing standard maintenance on the grid, to reduce any future burdens on the grid or their customers.

4.3 Grid Connection and Integration for Centralized Generation

Both connecting to and integrating with the transmission grid pose challenges for utility-scale variable generation. The production of utility-scale wind and solar facilities is far more location-dependent than that of fossil fuel-based plants, which consume portable (though often costly to transport) feedstocks. Therefore, finding a viable renewable generation site requires balancing the resource available at the location with its proximity to existing infrastructure. Even in parts of the country with strong renewable resources, the costs of grid extension may preclude capacity additions if they are borne by the power developer. For example, Jamaica's Wigton Windfarm continues to face problems with its associated grid infrastructure and operations.[11] (See Case Study 1.)

Preliminary Worldwatch calculations using the World Bank Model for Electricity Technology Assessment (META) demonstrate that overall grid connection does not present a significant additional cost for renewable energy development in Jamaica. Based on modeling results, even building a 50-kilometer transmission line—nearly five times the length required for Wigton—would contribute less than 1 U.S. cent per kWh to the cost of electricity from a new wind farm. (See Figure 4.2.)

In addition to grid connection needs, major players in Jamaica's power system, including OUR in its 2010 Generation Expansion Plan, have cited variability concerns as a central reason for limiting renewable energy penetration in the national grid. However, there are proven technical and operational systems that can overcome these challenges. In particular, Jamaica's current petroleum-dominated power plants can be quickly fired up and down in response to variable electricity generation from solar and wind capacity.

Grid flexibility—how quickly an electricity system can adjust electricity supply and load up and down—is important for meeting Jamaica's growing power demand, especially with a high penetration of variable renewable energy. Flexibility is a function of both the grid's physical characteristics and its operational and market design.[12] All grids require a certain amount of flexibility to balance fluctuations in demand throughout the hour and day, as well as unexpected changes in supply in situations such as malfunctions or severe weather events. The integration of variable generation adds another element of variability to the grid system and therefore generally requires greater grid flexibility.

Some of the physical characteristics that determine flexibility are out of the control of grid operators. For

Case Study 1. Connecting Wigton Windfarm to Jamaica's National Grid

Grid connection issues surrounding Wigton Windfarm, which was connected to the JPS grid in 2004 at its original 20.7 MW capacity, provide an illustration of potential barriers to grid connection for future utility-scale centralized renewable generation projects. Power generation at Wigton Phase I is transformed up to 24 kilovolts by a transformer at the base of each wind turbine, and then again up to 69 kV at a single substation. This substation is connected to the main JPS grid by 11.3 kilometers of new 69 kV overhead single transmission line.

Wigton constructed the new 11-kilometer transmission line and then handed it over to JPS for ownership and maintenance responsibilities. Since then, JPS has not adequately maintained the line, and Wigton has had to carry out its own line inspections. For Phase II, Wigton requested that OUR and the Government Electrical Inspectorate review JPS operations of the transmission line, and these entities confirmed maintenance deficiencies on the part of JPS. Despite this finding, JPS still had not carried out all of the necessary corrections over one year later.

Source: See Endnote 11 for this chapter.

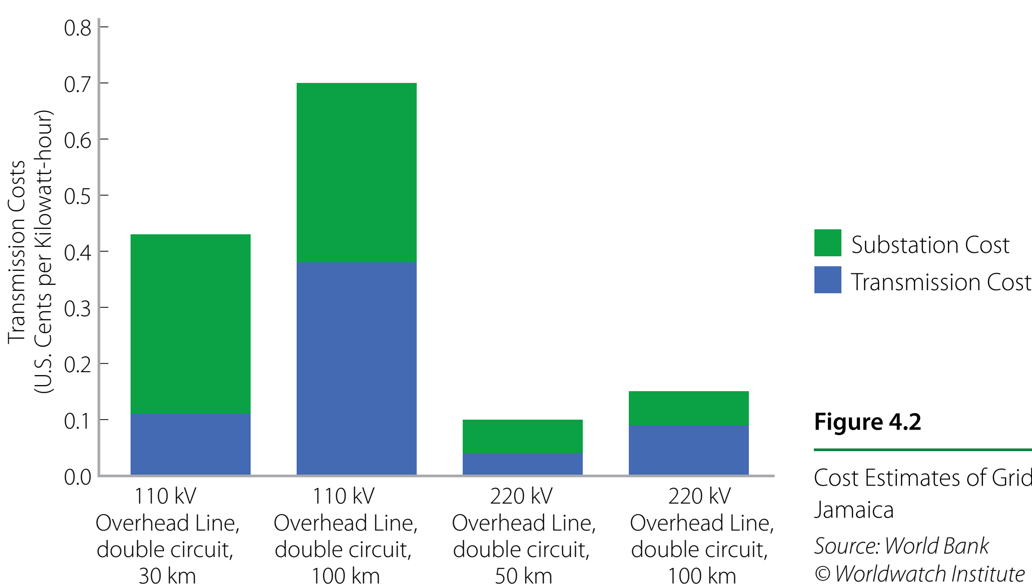

Figure 4.2

Cost Estimates of Grid Connection in Jamaica

Source: World Bank
© Worldwatch Institute

example, larger grids or balancing areas, whether measured by the number of generating facilities or the geographic area covered, are more flexible because variability in supply and demand can be smoothed by aggregation in balancing areas with more diverse types of power plants.

Small islands like Jamaica face a challenge in this regard because they tend to have small and geographically isolated grids. Although underwater electricity transmission lines can be built, the cost rises sharply with the distance and depths they must cross.[13] However, studies indicate how some island regions, such as Oahu in the U.S. state of Hawaii, would be able to integrate variable generation with the grid without sacrificing reliability.[14] (See Case Study 2.)

Grid planners do have control over other physical factors that affect grid flexibility. Upgrades to the grid infrastructure, including replacing aging transmission lines with new, higher-voltage lines, can reduce technical losses and improve the capacity of the grid to handle new renewable generation.

Case Study 2. The Potential for Integrating Wind and Solar into the Grid of Oahu, Hawaii

A recent study of the grid of Oahu, Hawaii, demonstrates the potential of even a small island grid to integrate wind and solar power without sacrificing stability. Oahu's grid is of a comparable scale to Jamaica's, with less than 1,800 MW of installed capacity and annual generation of around 8,000 GWh per year. The study examined the possibility of integrating up to 500 MW of wind and 100 MW of solar power into the grid, which would account for over 25% of the system's electricity production. It found that up to 95% of the wind energy generated could be successfully delivered to the grid, which, along with the solar generation, would lower fuel consumption by 30% without sacrificing the reliability of the system.

The study found that three relatively simple changes to the operations of the grid would allow Oahu to achieve these results. First, Oahu would need to use the latest wind-forecasting technology and commit its fast-start generating units ahead of time, reducing the need for regulation units to manage unexpected wind fluctuations. A simultaneous change would be an increase in the requirements for "up-reserve" (regulating units that run at a base level of generation that can be increased as the grid operator requires) to account for sub-hourly variation, since Oahu runs on hourly economic dispatch. These actions would both increase the amount of wind energy that can be accepted by the grid by 7% and lower the system's fuel costs by 14%.

The second step in the process would be to reduce the minimum stable operating level of the baseload facilities owned by the Oahu utility. Oahu is more reliant on coal than Jamaica, and 95% of its electricity comes from relatively inflexible units. All baseload plants have a minimum level of production at which they can safely operate. Often at times of low electricity demand, wind energy cannot be accepted because conventional baseload facilities are already meeting load requirements at this minimum level. If these minima can be lowered, more wind energy could be accepted by the grid. Implementing such a strategy would necessitate having a "down-reserve" (units that operate on a base level of generation that can be decreased as the grid operator requires) as well, to ensure stability in the event that load unexpectedly drops. This would increase the amount of wind energy that can be accepted by the grid by 14% and lower the system's fuel costs by 9%.

According to the study, the third change that would ease wind and solar integration on Oahu would be to reduce the up-reserve requirement by taking advantage of fast-start generation units and other resources at the grid operator's disposal. This would not affect the amount of wind energy accepted by the grid but would lower fuel costs slightly. These strategies raised the average heat rate of the power plants (the amount of primary energy required to produce a certain amount of electricity) because of the increased reliance on peaking units and reserve requirements, but fuel costs still fell by 30% overall. Operational complications remained, particularly dealing with sub-hourly variability, but the authors concluded that integration was possible without sacrificing stability.

Source: See Endnote 14 for this chapter.

JPS has been criticized for not extending and strengthening the grid—as noted earlier, the total length of grid lines has not increased since the company received sole transmission and distribution rights in 2001. These grid improvements are necessary to maintain a functioning grid and to accommodate growing energy demand in Jamaica, whether it is met with fossil fuels or renewable energy. During the 2004–09 operating period, JPS did perform grid system upgrades in the northwestern corridor of the island, which has been experiencing increased electricity demand from the tourism industry. The North Western System Improvement Project was a USD 4 million investment to upgrade two substations and increase voltage on primary distribution lines from 12 kV to 24 kV.[15]

Over the period from 2009 to 2014, JPS announced plans to spend USD 27.5 million for improvements to the transmission network. This includes USD 16.7 million for transmission line upgrades and infrastructure strengthening; USD 6.9 million to upgrade and replace aging breakers, reclosures, and substation transformers; USD 1.3 million for substation upgrades; and USD 0.7 in protection and control systems to improve grid stability and reliability.[16] JPS also plans to spend USD 7.4 million to further expand the transmission network to accommodate new loads, especially in the northwest.[17]

JPS also planned USD 104 million in expansions and improvements to the distribution network, including USD 48.1 to expand the grid to new customers, and USD 38.4 million to improve system reliability through replacement of wooden poles and transformers and improving voltage quality.[18]

These grid-strengthening measures should be expanded in order to connect new renewable power generation and increase the grid's capacity to meet rising electricity demand in Jamaica. Physical improvements to grid infrastructure will be necessary regardless of whether the country continues to rely on fossil fuel-based power or transitions to a renewable energy system.

4.4 Integrating Complementary Renewable Energy Resources

Some of the largest challenges associated with the variable nature of electricity generation from some renewable resources can be addressed by identifying complementary resources—that is, renewable potential from different sources or geographic areas that are strongest at different times of the day or year so that the weak period for one resource coincides with strong generation from another resource on the same grid. Solar and wind are both variable energy sources. Small hydropower in Jamaica is part firm capacity and part variable—about 15 MW of the total 23 MW of small hydro in the country is considered firm, while the rest is variable due to seasonal changes in stream flow.[19]

Wind power provides a particularly useful example of the benefits of integrating complementary resources, as intermittency is one of wind energy's largest challenges. The wind does not blow continuously but varies significantly throughout the year and the day. How pronounced this variation is, and how well wind resources with different variability patterns across the country can be integrated to reduce overall intermittency, go a long way to determining the viability of adding wind power to the electricity grid. Seasonal variation is useful for power-system planning and scheduling of long-term maintenance, whereas daily variation is especially important for examining if and when peak wind generation coincides with daily peak electricity demand.

Unfortunately, there is negligible difference between wind speed variability at different sites in Jamaica, meaning that building wind capacity in different sites will not likely have a significant smoothing effect on overall generation. There is partial seasonal complementarity between solar and wind resources, however: at assessed sites the winter peak in wind generation coincides with the lowest solar resource in winter. (See Figure 4.3.) Joint solar-wind generation could be used to maintain more consistent generation throughout the year. Variability data from the Wigton assessment sites will be useful to determine if other locations in Jamaica have more complementary wind resources.

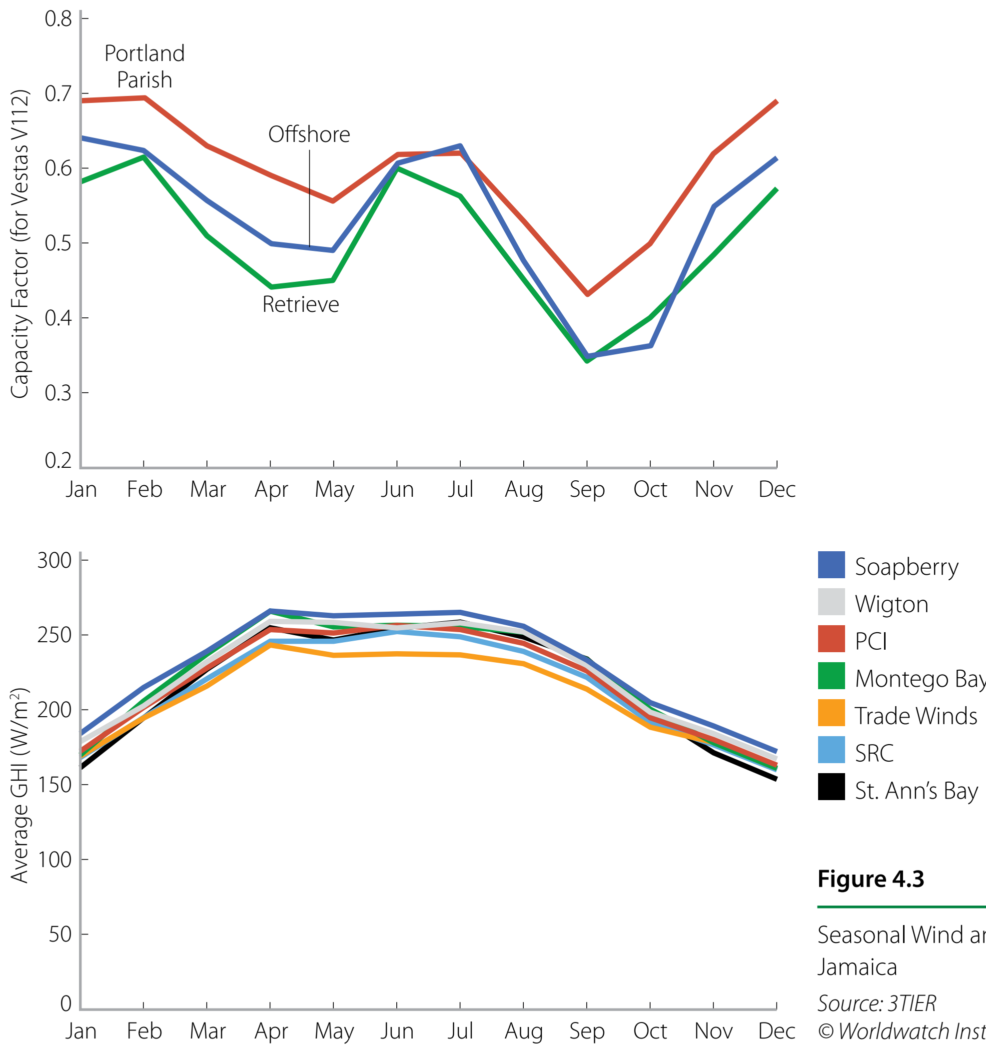

Figure 4.3

Seasonal Wind and Solar Variability in Jamaica

Source: 3TIER
© Worldwatch Institute

Wind resources also have relatively similar daily generation patterns. Because solar power production peaks at midday, around the same time as wind speeds, integrating these two resources reduces daily variability only minimally.* (See Figure 4.4.)

The correlations between renewable generation and demand also help determine the amount of variable

* As 3TIER notes, solar resource potential and daily and seasonal variability are nearly identical across all seven sites assessed in Chapter 3. Therefore, the daily global horizontal irradiance (GHI) curve at the Trade Winds Citrus Project site is presented here as representative data.

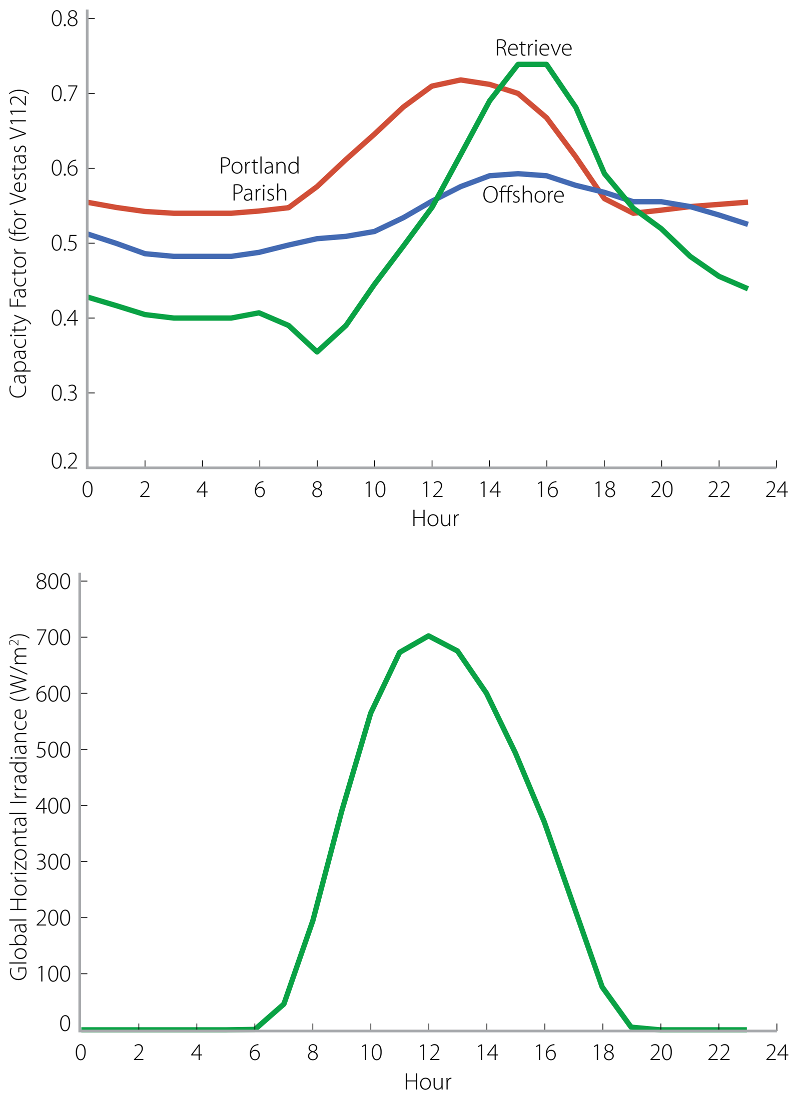

Figure 4.4

Daily Wind and Solar Variability in Jamaica

Source: 3TIER

© Worldwatch Institute

generation that can be comfortably integrated. If the peaks and valleys of wind or solar generation match up well with the peaks and valleys of demand, it is easier to fit them in with the rest of the generation system. Examining daily demand data can help energy planners match new renewable generation capacity to demand patterns.

The solar and wind resources assessed in this Roadmap correlate well with daily demand curves in Jamaica. Solar resources peak at midday, around the time of a demand bump, and wind resources (especially at the Retrieve site) are high in the evening when electricity demand is highest in Jamaica. (See Figure 4.5.)

4.5 Operations, Markets, and Forecasting

Operational matters also influence a grid's overall flexibility, not least because there are many situations where existing flexible generation cannot be accessed because of the grid's institutional framework or scheduling rules. Each grid is governed by grid codes that define how and whether wind or solar devices

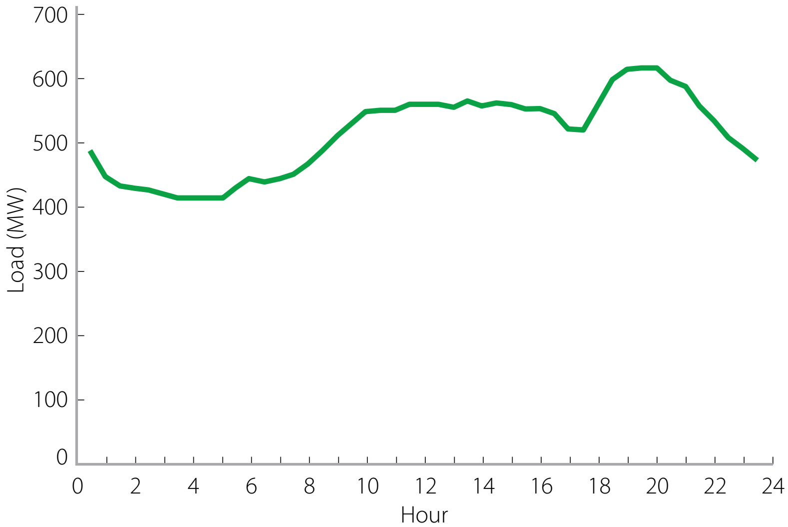

Figure 4.5

Typical Weekday Load Profile in Jamaica
Source: OUR

respond to certain grid conditions, including voltage sags and over-generation. If grid codes are not designed to accommodate wind and solar PV, grid operators may, for example, curtail more renewable energy than necessary.

The rate at which electricity markets operate affects grid flexibility as well, with close-to-real-time market clearing allowing for better response to unanticipated variability than hourly markets.[20] Within a single energy market, a range of time frames may exist: some generators provide constant, stable power and sign contracts far in advance because their maneuvering cost is too high to respond to price signals; others enter into new contracts (for a certain level of generation at a certain price) at the beginning of each market period; and still others respond to changes in load or supply within the market period as the grid operator requires. This last segment of the market, the ancillary services market, is typically the most expensive from the grid operator's perspective, because it requires generators to ramp production up or down quickly. These generators therefore sacrifice efficiency for flexibility, and require a high price to make such an arrangement worthwhile.

Historically, most energy markets have operated with an hour-long market period, so that those in that second category (intermediate and peaking generators) enter into new contracts with the operator each hour. This means that changes in load or supply within that hour must be balanced using regulation services. If this market period, providing economic dispatch, can be shortened to five or 15 minutes, as has occurred in many parts of the United States and elsewhere, the market provides greater incentive for generation flexibility, and there is less need to pay for regulation services.[21]

The reason for this is that the market clearing price will change more frequently, and the intermediate and peaking plants that can produce economically will then be more precisely fitted to the amount of energy needed to meet load over the market period. A study on the New York Independent System Operator (NYISO) found that providing intra-hour response in this way—relying on the economic incentives of a sub-hourly market—has been shown to come at no added cost. Freeing up generators that sell into the regulation market from having to respond as much to load changes provides more flexibility that can be used to smooth out variable generation ramps.[22]

The quality of wind and solar forecasting affects the ease of grid integration as well. The more accurately that variable generation producers and the grid operator are able to predict wind and solar production, the less they will have to rely on the regulation market to account for unexpected changes. Improving forecasting can be as simple as improving the methodology or technology used, but there are also operational elements. Multiple studies of wind forecasting have shown that forecast error is reduced significantly when aggregated over a large geographic area, suggesting that it is better to forecast production from a variable generation system as a whole rather than from each facility independently.[23] Forecasting error also decreases as it approaches real-time. Markets that operate with quicker economic dispatch are therefore better able to predict the amount of variable generation that they will have on hand during each market period.

Jamaica has definite room for improvement on these measures. Converting to faster dispatch, especially given the existing system's use of petroleum generating technologies, which are well suited to functioning as intermediate or peaking plants, would have considerable benefits for integration of variable generation.

The discussion of grid flexibility is based on the assumption that the grid operator must deliver the amount of power needed to meet the load at all times. The need to quickly adjust the energy delivered both up and down to respond to changes in load or variable generation is grounded in this requirement. In Jamaica, however, load shedding—temporarily suspending energy delivery to some customers—is used commonly to deal with generation shortages. If Jamaica continues to rely on load shedding, this in essence makes the integration of variable generation easier, because it provides a solution to a situation where unexpected drops of generation cannot be quickly counterbalanced.

If Jamaica is committed to ending its reliance on load shedding, however, high penetrations of variable generation could make the task more difficult. Both the effect of load shedding on integration of variable generation and the effect of this integration on any attempts to end dependence on load shedding deserve further discussion. Integration of variable generation should be handled carefully to avoid any increases in the need for load shedding. Planned demand management for select customer classes, particularly large consumers, could help demand respond to variable generation supply in an orderly and pre-agreed way.

4.6 The Role of Oil and Gas Generation in Offsetting Variability

The nature of non-variable power generation on the national grid can affect the electricity system's ability to respond to fluctuations in solar and wind generation. Quick changes in variable generation output must be counterbalanced by quick increases or decreases in output from other generators that are explicitly designated as being responsible (at the direction of the grid operator) for responding to such changes.

Some power-plant technologies are better suited to this task than others. Steam turbines powered by coal, for example, take a long time to ramp up and down, and they lose efficiency when they are not operating at their design load. Cycling places mechanical stress on these plants, potentially leading to higher maintenance needs and shorter lifetimes. Other plant technologies, such as oil or gas turbines or reciprocating engines, ramp up and down very quickly, and lose less efficiency when they are operating at partial loads.

By these metrics, Jamaica looks more attractive. The country's reliance on fuel oil and diesel means that a very large share of its generation system is of the more flexible variety. Diesel generators can provide back-up power to the grid during times of low renewable generation. Using diesel generation or even biodiesel for this purpose could allow for over 90% renewable electricity. (See Chapter 5.) The high cost of diesel fuel for electricity generation that currently dominates Jamaica's electricity sector would therefore have a relatively small effect on overall prices.

Jamaica's potential plans to diversify its energy system with liquefied natural gas (LNG) could also complement a renewable energy system. Because LNG can be quickly dispatched in response to demand fluctuations, it can be used to address renewable variability in the near to medium term.

4.7 Electricity Storage

Energy storage systems—including batteries, pumped hydropower, compressed air energy storage, molten salt thermal storage, and hydrogen—can address the intermittency challenge of variable renewable energy sources such as solar and wind.[24] (See Table 4.1 for an overview of technology options.) These systems store surplus renewable energy generated during periods where production exceeds demand, and dispatch this energy at times of low renewable generation.

Currently, battery systems are the most mature and widely implemented energy storage technology, and are therefore the most likely to be implemented in Jamaica in the near term. There also has been considerable interest in Jamaica in pumped-storage hydro systems, which could be paired with solar or wind farms sited near viable waterways. Assessments are needed to determine if there are sites with potential for pumped-hydro systems with limited ecological impacts associated with large hydropower development, as discussed in Chapter 3.

4.8 Curtailment

Curtailment at high penetrations of renewable energy generation refers to a reduction in the output from intermittent renewables to stabilize the electricity system when electricity supply exceeds demand for short periods of time. Curtailment requirements vary in day-to-day operations of the grid. The highest amount of curtailment occurs when generation exceeds demand even when conventional plants are operating at their minimum and fast-start units such as diesel generators are turned off.

Curtailment can be limited by creating a flexible electricity system through measures discussed throughout this chapter, including investing only in those fossil fuel-generation options (petroleum and natural gas rather than coal) that can react quickly to changes in supply by intermittent resources. This becomes increasingly important as the share of renewables increases. Coal use forms a barrier to a more accelerated renewable energy expansion and requires substantially greater amounts of curtailment than systems that use flexible natural gas or petroleum-based plants. Another option for limiting curtailment is the use of storage options.

From an economic perspective, curtailment should be reduced to a minimum. When curtailment is needed, mainly wind but also large solar generators are instructed by the grid operator to reduce output,

Table 4.1. Energy Storage Technology Options

Option	Description	Current Status of Technology	Scale of Technology	Cost per Discharge Power	Levelized Cost of Storage	Annual Operating Costs	Suitability for Jamaica
Lead-acid batteries	Used widely with off-grid technologies. Most commonly used to store electrical energy from PV systems, including at the household level.	Mature technology	10 MW or less	USD 300–800 per kW	USD 0.25–0.35 per kWh_{life}	USD 30 per kW per year	Suitable for off-grid applications. Environmental and health concerns arise from lack of maintenance and disposal of old batteries.
Nickel-cadmium (NiCd) batteries	Have higher energy density and cycle life than lead-acid batteries, but are more expensive.	Mature technology. As with lead-acid, used for standalone power systems but not considered suitable for bulk storage due to cost.	A few kW to tens of MW	USD 3,000–6,000 per kW (in bulk storage)	Data not available	Data not available	Same as above.
Lithium ion batteries	Rechargeable batteries used widely in mobile applications due to high energy density. Various types exist and offer different pros and cons.	Emerging technology. Need further development for power generation energy storage, but offer promise.	10 MW or less	USD 400–1,000 per kW	USD 0.30–0.45 per kWh_{life}	USD 25 per kW per year	Needs more R&D.
Liquid-metal (NaS) batteries	Other types of batteries are being developed for utility-scale storage applications. NaS batteries utilize the sodium-sulfur reaction and require high operating temperatures.	Emerging, pre-commercial technology	100 MW or greater	USD 1,000–2,000 per kW	USD 0.05–0.15 per kWh_{life}	USD 15 per kW per year	Expensive and not yet developed enough to be worthwhile. Potential to pair either with wind power could be useful in the future, once the technology is more developed.
Vanadium redox and zinc-bromine flow batteries (VRB and ZBB)	Flow batteries utilize electrochemical energy storage, just like lead-acid batteries, but require little maintenance. Large capacity potentials make VRBs suitable for wind energy storage, while ZBBs are more appropriate for smaller-scale systems.	Emerging, pre-commercial technology	25 kW–10 MW	USD 1,200–2,000 per kW	USD 0.15–0.25 per kWh_{life}	USD 30 per kW per year	Expensive and not yet developed enough to be worthwhile. Potential to pair either option with wind power could be useful in the future, once the technology is more developed.
Pumped-storage hydro	Most commonly used for large-scale energy storage, and to complement solar and wind. At times of low power demand, excess electricity is used to pump water uphill into a sealed-off reservoir. During periods of peak demand (or low energy production), the stored water is released through a hydropower plant, pushing a turbine that rotates a generator to produce electricity. Requires hydro resources and mountainous landscapes.	Mature technology	Typically 200 MW or greater	USD 1,000–4,000 per kW	USD 0.05–0.15 per kWh_{life}	USD 5 per kW per year	Very suitable. Assessments needed to identify viable sites.

Table 4.1. continued

Option	Description	Current Status of Technology	Scale of Technology	Cost per Discharge Power	Levelized Cost of Storage	Annual Operating Costs	Suitability for Jamaica
Compressed Air Energy Storage (CAES)	Functions similarly to pumped-storage hydro and fits well into a micro-grid system. During times of low energy demand, cheap electricity is used to power a motor, which runs a compressor that forces air into tight underground reservoirs. During periods of peak demand, the compressed air is released and heated with natural gas, causing the air to expand and push a turbine that drives a generator to produce electricity.	Mature technology. Expansion limited due to availability of natural storage sites.	500 MW or greater	USD 800–1,000 per kW	USD 0.10–0.20 per kWh_{life}	USD 5 per kW per year	Depends on availability of natural storage sites.
Thermal storage	Often used in conjunction with CSP systems. Relies on heat-absorbing materials, such as molten salt, to absorb and store heat. In such systems, several hours, and in some cases up to a couple of days, of thermal energy can be stored in molten salt. This stored heat can later be released to help generate electricity at night or on a cloudy day.	Demonstration projects under way.	MW-sized	USD 50 per kWh USD 375 per kW (@ 50 MW for 7.5 hours)	Data not available	Data not available	Depends on suitability of CSP generation for Jamaica.
Flywheel energy storage	Uses electricity to accelerate a rotor to very high speeds and stores the energy as rotational energy.	Emerging technology. Used mostly for uninterruptible power supply/ bridging power.	100 kW to 200 MW	USD 2,000–4,000 per kW	Data not available	USD 15 per kW per year	For bridging power applications at critical institutions (e.g., hospitals), potentially.
Superconducting Magnetic Energy Storage (SMES)	Stores energy in the magnetic field resulting from the flow of direct current through a superconducting coil that has been cooled below its superconducting critical temperature. SMES is highly efficient, losing less of its stored energy than any other energy storage system. Can be dispatched very quickly.	Emerging technology. Used for short-duration energy storage and power-quality improvement. Numerous technical challenges still to be overcome.	1 MWh units in use for power quality control and grid stability; 20 MWh unit is a test model; currently viable for short-term power (seconds) in the 1–10 MW range.	Estimated capital costs of USD 200,000–500,000 for systems with energy storage capacity between 200 kWh and 1 MWh. Costs often vary based on current.	Data not available	Data not available	Not suitable due to expense and limited application.
Electrochemical capacitors	Stores energy in the electrical double layer at an electrode/electrolyte interface.	Still under development for use with renewable power systems.	Commercially viable for hundreds of kW scale for short power needs (seconds); utility-scale, longer-term (hours) storage not currently feasible.	USD 1,500–2,500 per kW (projected)	Data not available	Data not available	Not suitable.

Table 4.1. continued

Option	Description	Current Status of Technology	Scale of Technology	Cost per Discharge Power	Levelized Cost of Storage	Annual Operating Costs	Suitability for Jamaica
Hydrogen storage	Hydrogen is produced through the electrolysis of water or the reforming of natural gas with steam. The hydrogen is then compressed or liquefied and stored for later conversion to electrical energy.	Future technology. Barriers still exist with regard to hydrogen storage and safety.	MW-sized	N/A	Data not available	Data not available	Not suitable.

thereby losing out on revenue. Systems with large curtailment needs can decrease investment security and investor interest in the market. Support policies for renewables can counteract this fear and may include compensating renewably produced electricity even if it is curtailed.

Curtailment of wind and solar power should also be minimized because once wind parks have been constructed or solar panels installed, electricity comes at marginal costs of production nearing zero. The use of conventional power, on the other hand, requires fuel expenditures that could be avoided if the renewably produced electricity is consumed in its place. At the same time, curtailment needs should not prevent Jamaica from accelerating its renewable energy use. Jamaica's goal should rather be to build a system that is as flexible as possible to minimize curtailment but still reap the benefits of a sustainable energy system.

4.9 Summary of Grid Improvements for a Renewable Energy System

Enormous opportunities exist in Jamaica for renewable energy development. Distributed generation is particularly attractive because of the high losses in the existing transmission and distribution system and because many residential and commercial customers already have inverters and batteries for back-up power.

Both distributed and centralized wind and solar generation will pose technical challenges that will need to be addressed. Grid strengthening to accommodate distributed generation should be incorporated into maintenance and upgrades to distribution networks. Improving the reach and capacity of the transmission grid should be a top priority to allow for the acceptance of greater amounts of variable generation, especially from centralized utility-scale power plants.

With improvements to grid infrastructure and responsiveness, the amount of flexible generation available from Jamaica's conventional power plants suggests that a substantial amount of variable generation can be successfully integrated into the national grid. In particular, Jamaica can make use of its existing diesel power plants and distributed diesel generators to respond quickly to changes in power demand and variable generation intermittency. Integrating multiple renewable energy resources—including solar, wind, small hydropower, and biomass—can further reduce daily and seasonal variability issues.

Many of these grid improvements are necessary to meet growing energy demand in Jamaica, regardless of the energy source. Policymakers and regulators, including MSTEM and OUR, should ensure that JPS and other electricity system actors undertake the grid strengthening and expansion measures described above.

5 | Technological Pathways for Meeting Jamaica's Future Electricity Demand

Key Findings

- A sustainable Jamaican electricity sector based on a share of more than 90% renewable energy by 2030 is technically feasible.
- Rising national energy demand requires substantial construction of new generating capacity. A renewable energy share of 50% by 2030 would merely cover new demand but not replace existing conventional power.
- Worldwatch scenarios show that Jamaica can achieve a transition to a renewable-based energy system through different transitioning strategies, with natural gas and petroleum being better transitioning fuels than coal.
- Investments in new coal plants will ultimately limit the amount of renewable energy the system can integrate, and result in much larger renewable energy curtailment at times of peak production.
- Natural gas and oil-based generation plants are more flexible solutions, with fast ramp times and lower minimum operating levels, allowing a smoother integration of larger renewable energy shares.
- An accelerated renewable energy expansion might be in conflict with ensuring profitability of newly built conventional power plants as their capacity rate significantly reduces over time.
- Storage solutions can facilitate renewable energy integration and reduce curtailment needs. Lead-acid batteries are already economically available solutions that can smooth integration. Newer technologies promise to become available before 2030.

Chapter 4 has shown that Jamaica's electricity grid, while in need of repair, can integrate growing shares of intermittent resources. The costs of expanding existing grid structures to accommodate renewable energy are manageable, particularly if compared to overall renovation needs.

Assuming that transmission and distribution infrastructures do not pose a barrier to future electricity supply, this chapter builds on the grid integration analysis to assess different technological pathways for the future of Jamaica's electricity sector. The pathways outline different solutions for how Jamaica can meet projected future demand at all times.

This chapter first presents demand projections that build the foundation for evaluating the development of Jamaica's future electricity generation mix. It then discusses the different scenario types and details their results. The discussion distinguishes between an annual analysis, which assesses how yearly demand can be secured in all scenarios, and an hourly analysis, which offers a higher resolution for meeting demand on an average day in 2030.

The chapter concludes that an electricity system based largely on renewable energy is technically feasible. Investments in new coal-fired power plants ultimately limit the share of renewables that the system can integrate. The use of new gas plants or prolonged use of existing petroleum-based power plants is more suited to integrate growing shares of intermittent resources.

5.1 Demand Projections

In our scenario analysis, we evaluate how future electricity demand can best be met by different generation technologies. These assessments rely on existing projections of annual generation and peak demand developed by Jamaica's Office of Utilities Regulation (OUR) in 2010.[1] OUR derived three different demand scenarios—low, base, and high—based on varying assumptions about factors such as expected income, GDP, exchange rates, electricity pricing, demographics, and energy intensity. (See Figure 5.1.)

For our analysis, Worldwatch uses OUR's base-growth demand projections because these best reflect historical developments. The high-growth scenario has become very unlikely given Jamaica's faltering economic performance in the years since the projections were made. Electricity demand has the opportunity to be lower—approximating the levels in the low-growth scenario—if the country can make use of its energy efficiency potentials. (See Chapter 2.) Worldwatch adopts the base-growth scenario to show that a transition to a more sustainable energy system can be achieved even under more conservative assumptions—if a higher demand can be met by renewables, then this should be even easier for lower demand.

5.2 Scenario Types

Worldwatch's scenarios assess how growing shares of renewable energy can be used to meet future energy demand. The scenarios are differentiated by the level of penetration of renewables by 2030 and the

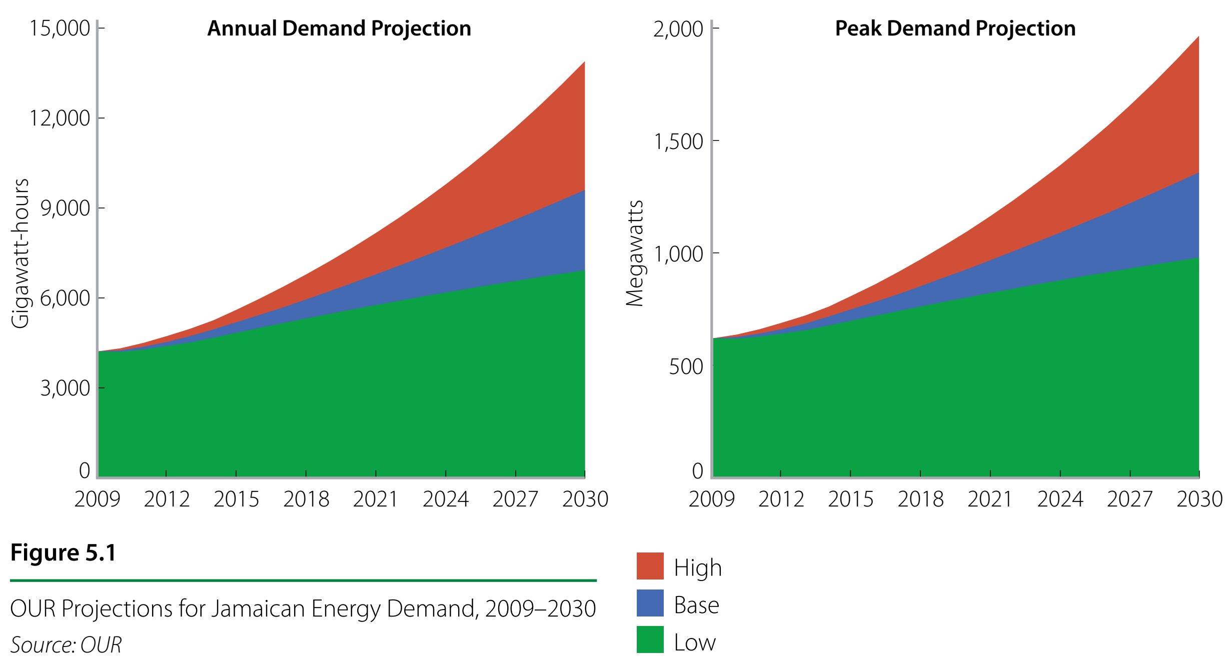

Figure 5.1

OUR Projections for Jamaican Energy Demand, 2009–2030

Source: OUR

conventional fuel used in the transitioning phase. All renewable energy transition scenarios are compared to a business-as-usual (BAU) scenario that assumes that, despite growing demand, Jamaica's current electricity mix of 95% oil-based generation and 5% renewable sources remains unchanged to 2030, and that all new generation would come from efficient combined-cycle power plants.

Worldwatch's transition scenarios all assume growing shares of renewables to 2030. (See Table 5.1.) In the two most ambitious scenarios, renewable energy technologies meet 94% of electricity consumption in 2030. Given Jamaica's current low share of renewables, the country will have to rely on conventional power during its transition to ensure that demand is met at all times. The scenarios reflect three different transitioning pathways for achieving the varying renewable energy targets:

a) Scenario 1: Building new natural gas power plants and repowering newer oil-based generation in addition to renewable energy expansion.
b) Scenario 2: Building new coal power plants in addition to renewable energy expansion.
c) Scenario 3: Extending the lifetime of existing oil-based generation in addition to renewable energy expansion.

Although Jamaica's current electricity mix does not contain coal or natural gas, the government has frequently discussed and considered these options, and they are therefore included in our assessment.[2] We also include scenarios with an expanded lifetime of petroleum-fired plants to assess if the construction of new conventional plants can be avoided by an accelerated expansion of renewables with necessary back-up through oil-based generation.

Table 5.1. Worldwatch Scenarios for a Renewable Energy Transition in Jamaica by 2030

Scenario 1 (Baseload Expansion: Natural Gas)		Scenario 2 (Baseload Expansion: Coal)		Scenario 3 (Baseload Expansion: None)	
	Renewable Share of Installed Capacity		Renewable Share of Installed Capacity		Renewable Share of Installed Capacity
BAU	5%	BAU	5%	BAU	5%
1a	20%	2a	20%	3a	20%
1b	30%	2b	30%	3b	30%
1c	50%	2c	50%	3c	50%
1d	70%	2d	70%	3d	70%
1e	94%	2e	81%	3e	94%

We assume for our transition scenarios that the first new coal and natural gas plants come on line by 2015, and additional capacity is then added depending on necessity. In Scenarios 1 (natural gas) and 2 (coal), older oil generation units are retired periodically, according to their age and efficiency. Furthermore, for the natural gas expansion scenarios, recently commissioned oil generation will be repowered to fire natural gas.[3] Petroleum coke-based generation is also considered for expansion as PCJ intends to upgrade its refinery and to make petroleum coke available by 2020.[4] At its current capacity, however, the refinery can produce only enough petroleum coke to supply 100 MW of generation. Scenario 3 (oil) assumes that the lifetime of existing petroleum-based power plants is extended to ensure enough supply capacity to meet demand at all times during the year.

Renewable energy sources are expanded in all three scenarios to achieve a specified share of installed capacity. For hydropower, PCJ estimates that 75.3 MW of electricity can be produced given the current resource.[5] Bagasse-based electricity generation is limited by the amount of sugar cane that can be harvested and processed by sugar producers and by the power generation potential per ton of bagasse.[6] In 1991, Jamaica harvested the largest crop of sugar cane to date, and based on this capacity a maximum of 100 MW of bagasse-based generation can be supplied.[7] Energy generation from wind and solar was estimated based on Worldwatch's and 3TIER's resource assessments.

5.3 Scenario Results: Yearly Analysis

Figures 5.2 to 5.6 demonstrate how annual electricity demand from 2012 to 2030 can be met in the different scenarios. In the BAU scenario (see Figure 5.2), new petroleum plants will have to be built; in Scenarios 1, 2, and 3, the results show different pathways for an increasing role of renewable energy. As renewables are expanded in the three scenarios, electricity generation from other resources, particularly petroleum, is decreased.

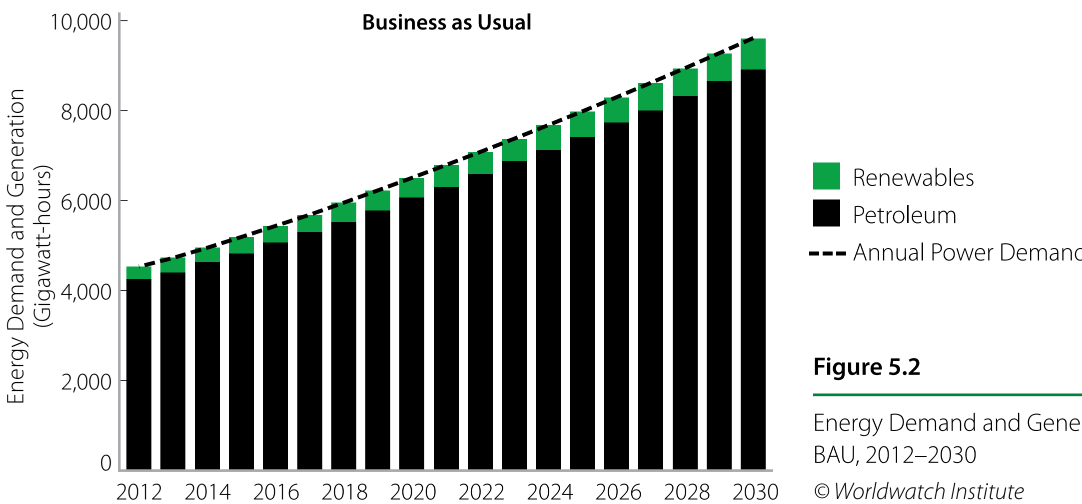

Figure 5.2

Energy Demand and Generation Under BAU, 2012–2030

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Investments in natural gas power (Scenario 1) or coal power (Scenario 2) can initially increase demand security if investments in renewable energy experience a slow start. As Scenario 3 (oil) shows, however, Jamaica does not need to rely on the construction of new conventional power plants to meet future demand as long as renewable energy capacities are built up quickly. Existing petroleum-based technologies can successfully complement a mix of new renewable technologies, while older plants are still phased out until 2020.

Given OUR's demand projection, a renewable energy share of 50% of total electricity generation is needed if additional demand growth alone is to be covered by renewable sources. Only renewable energy shares beyond that threshold will serve to displace conventional power capacities beyond current levels.

Results from Scenario 1 (see Figure 5.3) show that investments in natural gas capacities can quickly reduce the use of oil for electricity generation, accelerated through the repowering of newer petroleum-based generation technologies to run on natural gas. Investments in gas power also work well with renewables, allowing for a maximum share of up to 94% renewables by 2030. Natural gas plants are effective in integrating intermittent resources because they can be ramped up and down much more quickly and can also run at capacity rates as low as 15% without having to be turned off. At 94% renewable energy in 2030, Scenario 1 assumes that combined-cycle gas plants run at their minimum capacity and that converted diesel generators that are approaching the end of their lifespan are turned off but can serve as an additional reserve if needed.

In Scenario 2 (see Figure 5.4), coal power largely replaces the use of petroleum-based plants, at least in the short term and for the cases with lower renewable energy penetration. An electricity sector with coal plants will eventually run into problems integrating new intermittent sources of generation. New coal plants limit the technical availability to accommodate large shares of renewable energy given their inflexibility compared to gas plants or diesel generators. They cannot be turned up and down as quickly as is needed to deal with potential intermittency issues (see also hourly analysis in Section 5.4). Coal plants also cannot run below a certain capacity factor—around 40%—which limits the absolute maximum possible share of renewable energy to 81% in 2030. However, the system already becomes difficult to manage at lower shares and is likely to produce excess supply at times with strong winds and good solar radiation, making overall shares over 70% very unlikely.

Results for Scenario 3 (see Figure 5.5) show that new conventional power plants are not necessary in the transition to an electricity system based largely on renewables; however, an accelerated renewable energy expansion is required. Future demand, as projected by OUR, is met only under the cases with 70% and 93% renewable energy penetration. Newer petroleum-based generation plants are suitable for load-balancing tasks and offer system flexibility similar to that of natural gas plants.

Although Jamaica starts with a comparatively low share of renewable energy, the necessary capacity additions for an accelerated transition to a largely renewables-based system are manageable. Figure 5.6 shows the necessary capacity additions for the high renewable energy penetration case in Scenario 3. Overall, the country needs to add less than 3,500 MW to increase its renewable energy shares to 93% by 2030.

The expansion plan is modest in comparison to investments in other countries. Germany added 7,600 MW of solar PV in 2012 alone. In the developing world, India's installed solar capacity increased by around 1,000 MW. With regard to wind power, China added around 15,000 MW of wind power in 2012 alone, more than 11 times the amount that Worldwatch estimates for Jamaica over the next 17 years to reach 93% renewable power generation by 2030. In 2012, Romania's installed wind capacity grew by 900 MW, India's by about 2,300 MW, Brazil's by 1,100 MW, and Mexico's by 800 MW.[8]

As the solar and wind power industries have matured, progressively more markets are being served. Growing numbers of developing countries are attracting finance in the amounts needed to put Jamaica on a path to a clean electricity sector.

Although Figure 5.6 demonstrates the renewable energy investments required to meet energy demand by 2030, the phaseout of conventional power plants could be accelerated by expanding renewable energy capacity in earlier years. This more-rapid deployment of renewable energy would strengthen the benefits of Scenario 3 relative to Scenarios 1 and 2 by avoiding investments in new conventional power that would

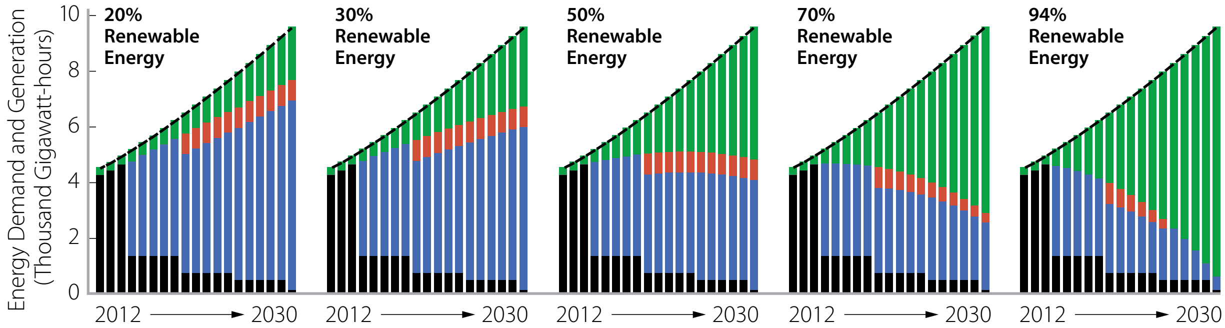

Figure 5.3

Energy Demand and Generation Under Scenario 1 (RE/Gas), 2012–2030 © *Worldwatch Institute*

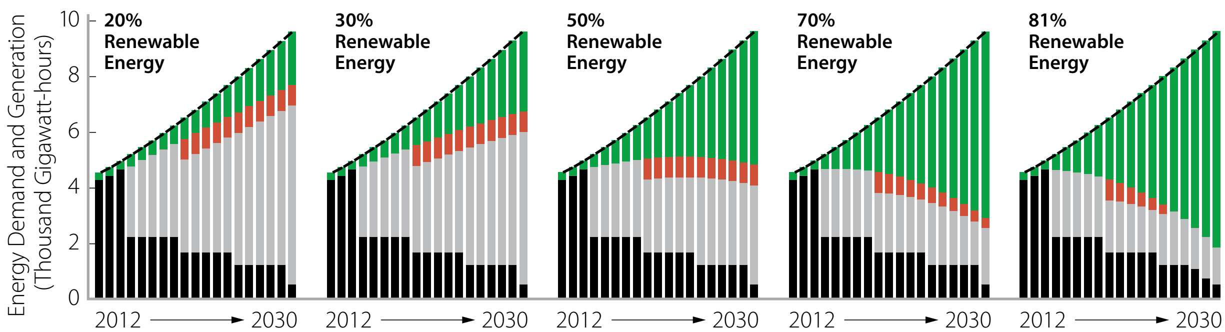

Figure 5.4

Energy Demand and Generation Under Scenario 2 (RE/Coal), 2012–2030 © *Worldwatch Institute*

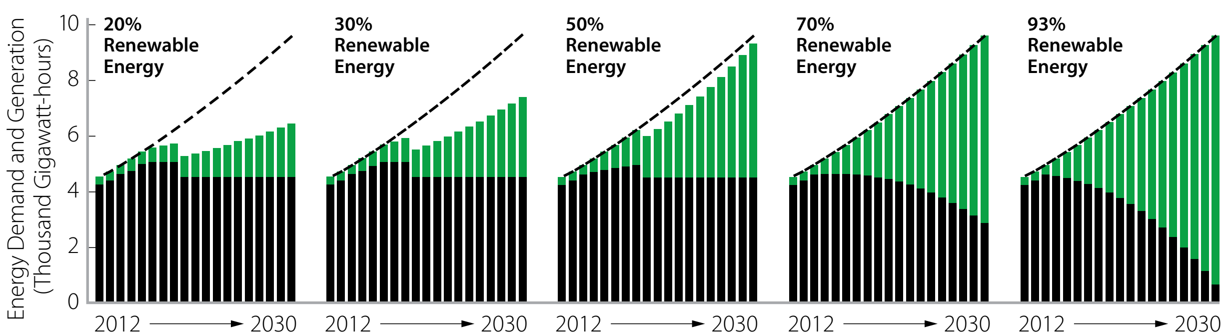

Figure 5.5

Energy Demand and Generation Under Scenario 3 (RE/Oil), 2012–2030 © *Worldwatch Institute*

Renewables Petcoke Natural Gas Coal Petroleum --- Annual Power Demand

be underutilized in cases of high renewable energy penetration. In addition, Jamaica would save even more on avoided fossil fuel import costs than estimated in Chapter 6 of this Roadmap.

Our technical scenario analysis illustrates that Jamaica can reach a high share of renewable energy

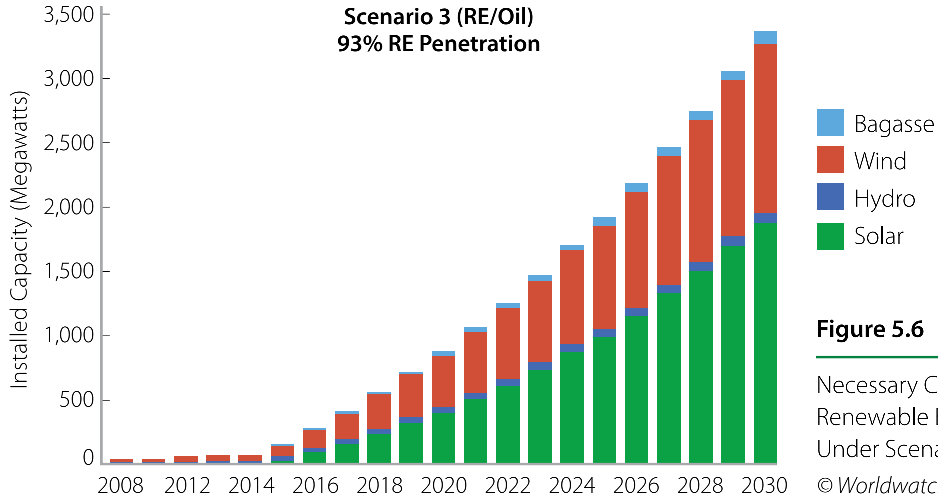

Figure 5.6

Necessary Capacity Additions for High Renewable Energy Penetration to 2030, Under Scenario 3

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through three very different transitioning pathways. The capacity rate at which conventional plants are run decreases progressively with growing renewable energy shares. Such a transitioning path is optimal for Scenario 3, where older petroleum-based plants will have to be retired over time. The picture is slightly different for Scenarios 1 and (particularly) 2, however, likely resulting in some stakeholder concerns about the profitability of natural gas or coal investments. As new natural gas plants (Scenario 1) and coal plants (Scenario 2) are initially run at high capacity factors but then increasingly less utilized with growing shares of renewable energy, the profitability of building such plants might be jeopardized.

Investors are unlikely to build new plants unless they believe that they can recover all their investment costs. The problem is aggravated for Scenario 2, since coal plants usually have longer lifespans and amortization periods to recover initial investment costs. The profitability of natural gas plants will depend highly on the compensation that can be offered for providing important load-balancing services and emergency back-up capacities.

5.4 Scenario Results: Hourly Analysis

The scenarios above were developed on the basis of annual demand and annual average generation capacity factors. This section, in contrast, analyses key scenarios on an hourly scale to assess how intermittent renewable energy sources behave throughout the day and how dispatchable generation sources, given their operational limitations, can help address some of the variability.

The analysis done here uses the load profile from a typical day in 2030 with a peak demand of 1,358 MW. It is important to note, however, that the load profile will likely change depending on the season and type of day (weekday or weekend/holiday). This will subsequently alter peak demand and the amount of penetration from each generation source, particularly from renewables. Nevertheless, an assessment of a typical day offers a good indication of the technical and economic challenges and opportunities that arise in an electricity system with high penetration of renewables.

The following analysis takes into account hourly resource potentials for wind and solar. Resource assessments, as discussed in Chapter 3, show the hourly supply of intermittent resources through a 25-year period. A grid-level electricity system analysis can be carried out using the resource assessments for wind and solar as well as utilization rates, minimum operating levels, and ramp rates for specific dispatchable power sources. This analysis evaluates how electricity that is generated hourly from each resource compares with electricity demand, enabling an assessment of the amount of load balancing needed at times of particularly high or low levels of intermittency.

An hourly analysis of the future electricity system is an important step toward generation system planning, because the goal for any utility is to provide reliable and uninterrupted electricity services at all times. A grid-level hourly analysis can also reveal the maximum penetration of renewable energy that an electricity grid can manage on a typical day in 2030. Worldwatch has used this method to calculate the upper limit of annual renewable electricity generation, as discussed in Section 5.3.

In our assessment, we performed hourly electricity system analyses for all renewable energy scenarios. (This section presents only key scenarios, however.) Here, we assume that intermittent sources of electricity are not curtailed and that dispatchable sources can be ramped up or down, according to power plant type and specification, to meet demand.

Our analysis assumes a functioning grid with minimal losses. This seems reasonable because it is expected that Jamaica will upgrade and extend its transmission system in order to reach and integrate cheap renewable energy. (See Chapter 4.) Also, our analysis assumes that power is dispatched according to price—that is, that the generator with the lowest cost of producing electricity is given preference on the grid.

Demand for electricity services changes continuously throughout the day, season, and year. A load profile or system curve represents graphically the behavior of electricity demand in a specified period of time. The hourly analysis done in this chapter is based on the load profile shown in Figure 5.7, and is essentially an exercise in meeting demand with various economical generation sources. For Jamaica's case, this analysis is performed for a typical weekday in 2030.

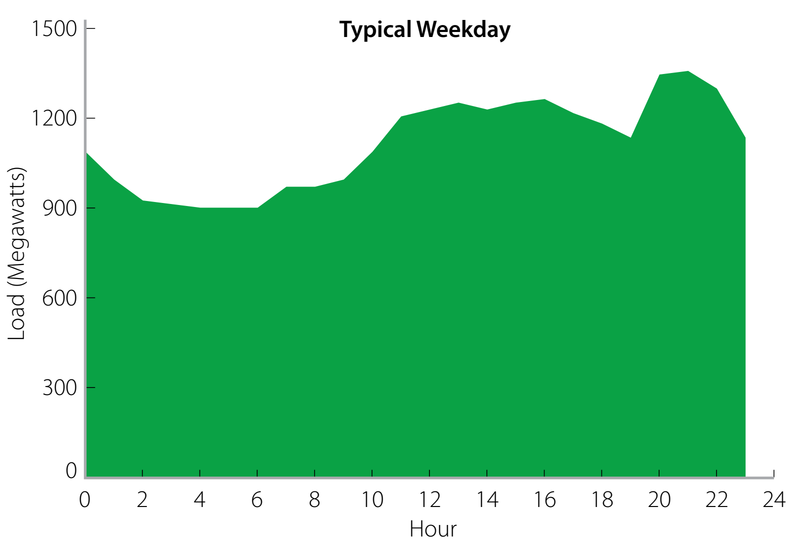

Figure 5.7

Projected Load Profile in 2030
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Jamaica's load profile in 2030 was estimated assuming that today's profile characteristics, such as times of peak demand, remain the same, but that demand levels are higher. The basis for the load profile was the system curve for a typical weekday in 2008 as reported in JPS's 2009–2014 Tariff Review Application submitted to OUR. The load profile in 2030 has a projected peak demand of 1,358 MW.

At 50% annual renewable energy consumption and an expanding natural gas generation portfolio, the hourly analysis for Scenario 1 shows that there is almost no excess generation on the grid, and the maximum renewable energy penetration during the day is almost 88%. (See Figure 5.8.) At 94% annual renewable energy consumption, the hourly analysis shows that there is excess generation on the grid, and about 31% of the daily wind and solar generation will have to be curtailed unless electricity storage becomes available.

At a 94% renewable consumption share, the maximum renewable energy penetration during the day is 96%. This maximum also occurs at noon when renewable generation is at its peak and conventional

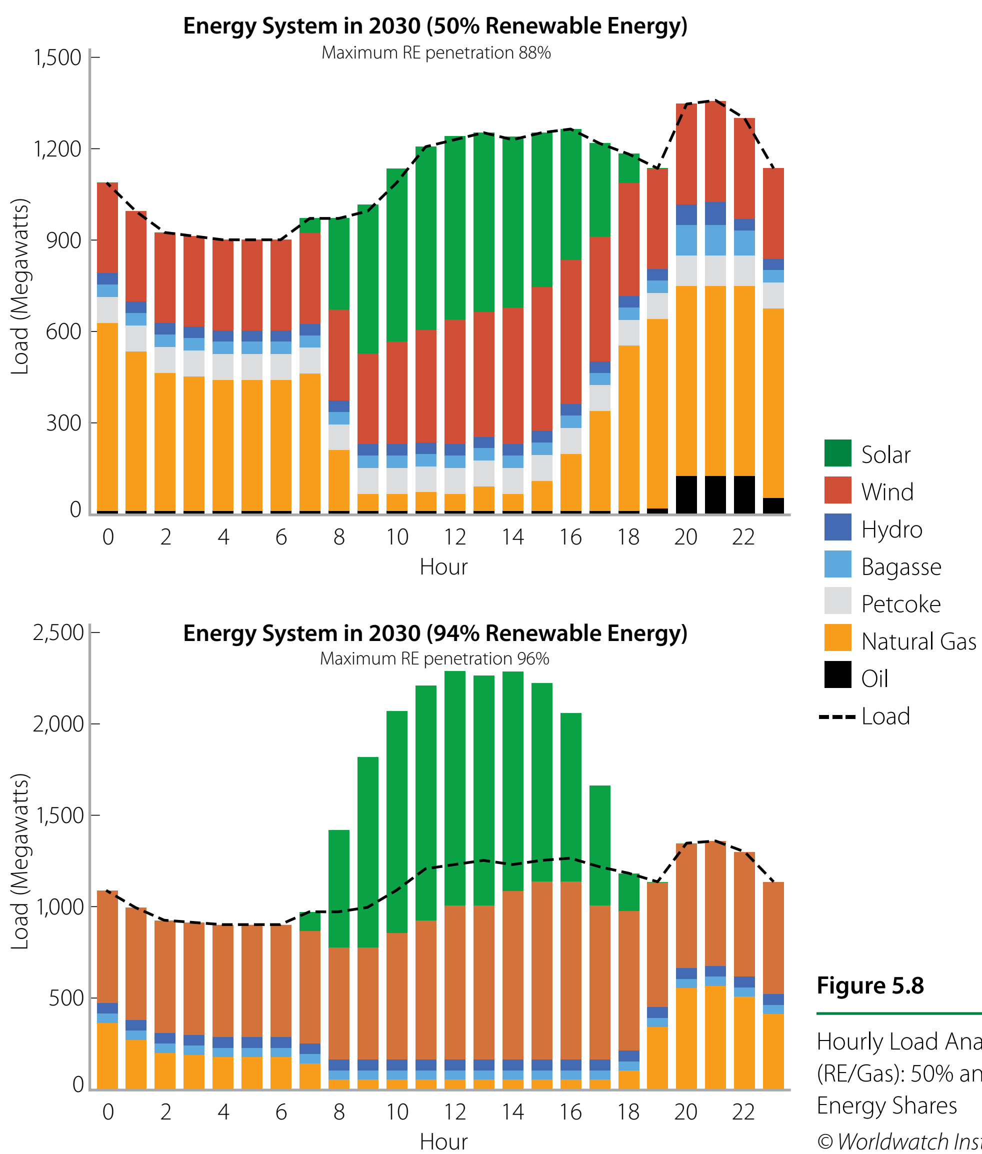

Figure 5.8

Hourly Load Analysis Under Scenario 1 (RE/Gas): 50% and 94% Renewable Energy Shares

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generators are operating at their minimum capacity. This is the highest renewable generation penetration possible from all the scenarios analyzed in this chapter, as natural gas is a very flexible source of generation with quick ramp times and low minimum operating levels.

The results of Scenario 2 indicate that a reliance on coal power for baseload generation would severely limit Jamaica's ability to integrate larger shares of renewable energy. (See Figure 5.9.) At 50% annual renewable energy consumption and an expanding coal generation portfolio, the system already has to manage significant excess generation on the grid as coal plants are not able to be run more flexibly. In this scenario, approximately 15% of daily wind and solar generation will have to be curtailed. The maximum renewable energy penetration reaches 71%.

At 81% annual renewable energy consumption, the required daily curtailment increases to 31% of renewable generation, while the maximum renewable penetration reaches 83%. Curtailment in Scenario

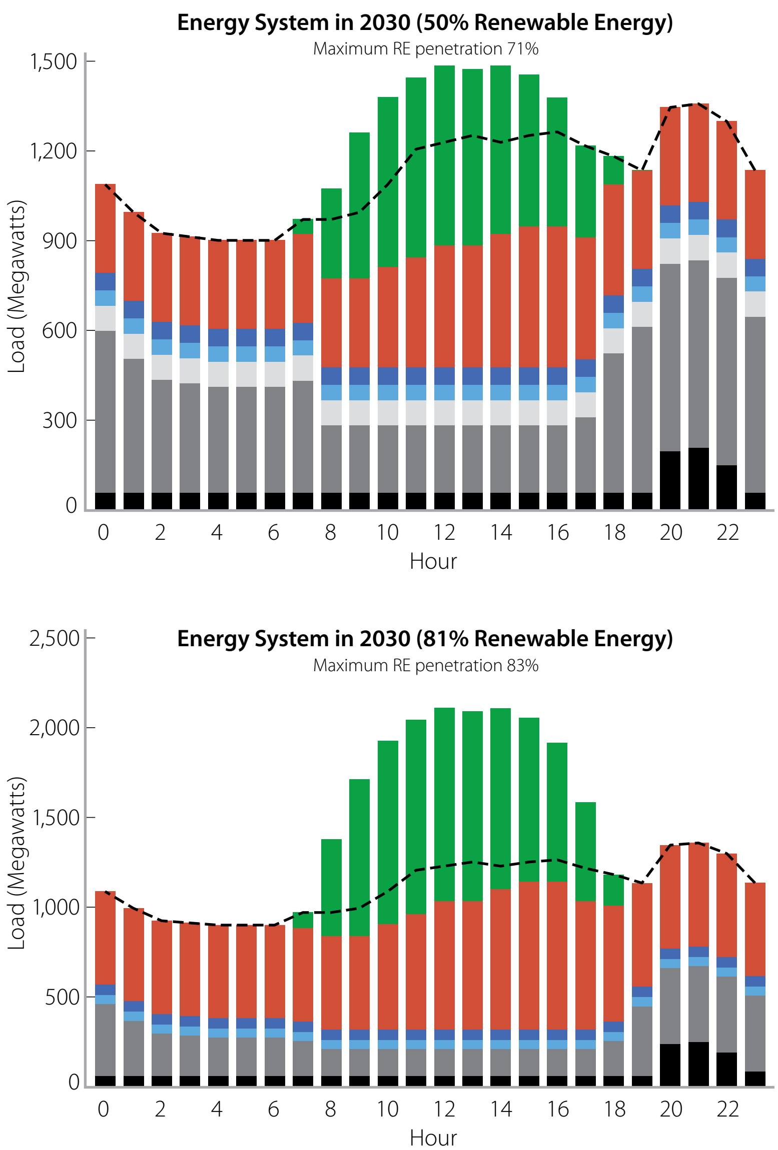

Figure 5.9

Hourly Load Analysis Under Scenario 2 (RE/Coal): 50% and 81% Renewable Energy Shares

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2 (RE/coal) is significantly higher than in Scenario 1 (RE/gas). Coal-fired power plants have slow ramp times and higher minimum operating levels than natural gas plants and are therefore less equipped to successfully integrate renewable energy.

In Scenario 3, at 50% renewable energy consumption and a solely renewables-based expansion portfolio, supply is unable to meet demand. (See Figure 5.10.) To ensure that demand is met at peak times in the evening, Jamaica has to build up renewable energy more quickly. At 93% renewable energy consumption, supply is able to meet demand. However, this scenario also produces excess electricity which requires a 31% curtailment of daily wind and solar generation. In this scenario, maximum renewable penetration reaches 94%.

Overall, Worldwatch's hourly analysis exemplifies the importance of creating a flexible electricity system if the goal is greater long-term renewable energy shares. Jamaica can ensure this by investing only in those

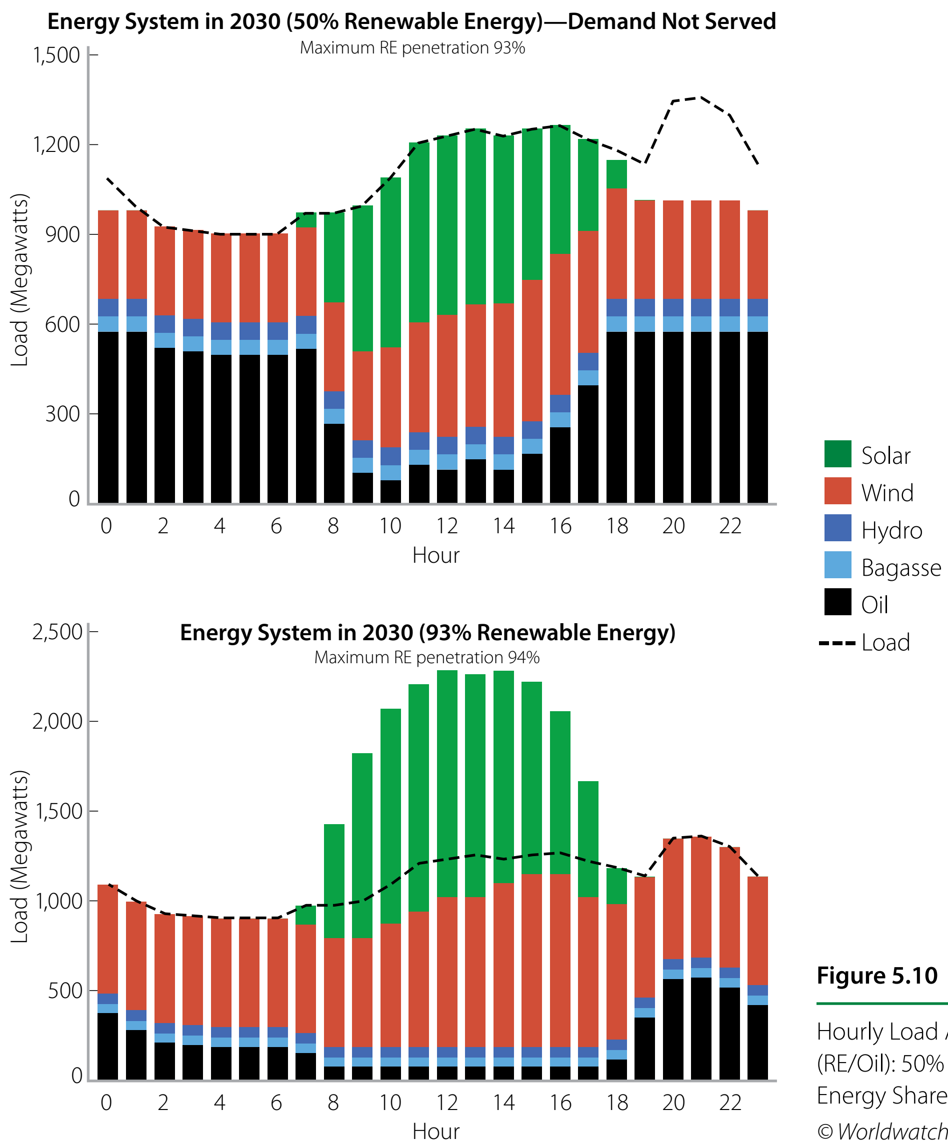

Figure 5.10

Hourly Load Analysis Under Scenario 3 (RE/Oil): 50% and 93% Renewable Energy Shares

© *Worldwatch Institute*

fossil fuel generation options that can quickly react to changes in supply from intermittent resources. Natural gas plants and oil-based generation technologies are more suitable for this task than coal power plants. As has been shown, coal use forms a barrier to a more accelerated renewable energy expansion and requires substantially greater amounts of curtailment.

This analysis was conducted assuming that Jamaica's power demand will increase but that the characteristics of the demand curve, such as times of peak demand, will otherwise remain the same. It is possible, however, that as Jamaica continues to industrialize, the characteristics of its demand curve will change, showing a more pronounced demand peak during midday. This would help alleviate some of the curtailment issues illustrated in the scenarios above, as generation from renewable energy sources—particularly solar—peaks at this time.

5.5 Scenario Results: Storage

Electricity storage also can be used to address the issue of variability and curtailment in Jamaica. Storage minimizes the level of curtailment for renewable generation, as any excess generation can be used for electricity storage. In Jamaica, excess electricity can be stored in batteries and used to supply the grid during times of low wind and solar resource availability. Even with energy storage, however, the analysis indicates that in a coal expansion scenario, curtailment is still relatively high due to the inflexibility of the system.

When energy storage is added to Scenario 1 (natural gas) with 94% renewable energy consumption, the curtailment of wind and solar generation decreases from 31% to 18%. (See Figure 5.11.) Curtailment reductions also can be seen in Scenarios 2 and 3. In Scenario 2 (coal), with 81% renewable energy consumption, curtailment of wind and solar generation decreases from 31% to 25%. (See Figure 5.12.) Compared to the other scenarios, the addition of energy storage in Scenario 2 leads to the lowest reduction in curtailment. In Scenario 3 (oil), with 93% renewable energy consumption, curtailment of wind and

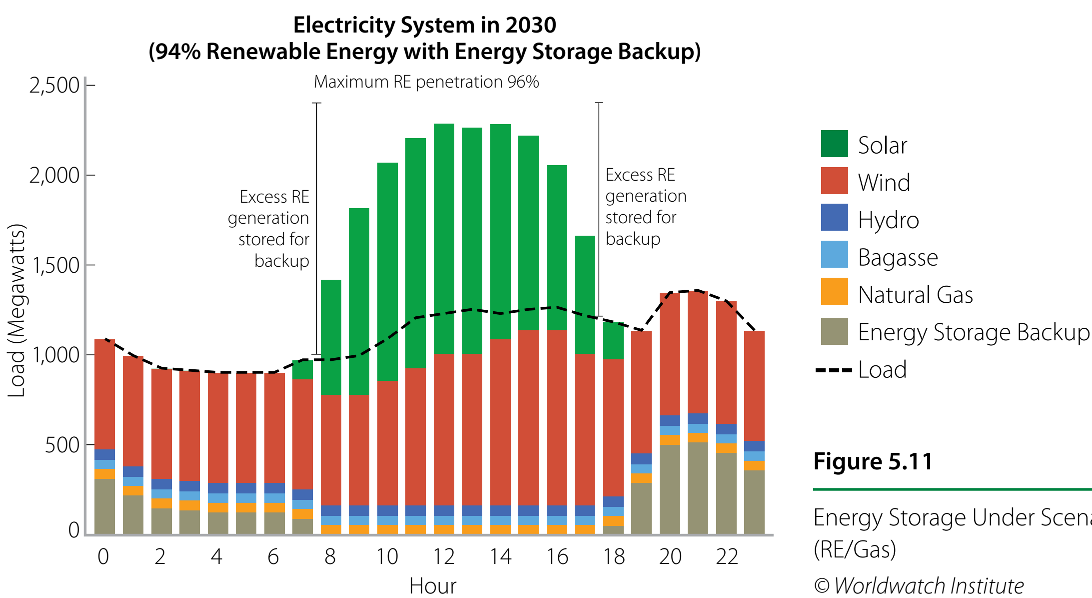

Figure 5.11

Energy Storage Under Scenario 1 (RE/Gas)

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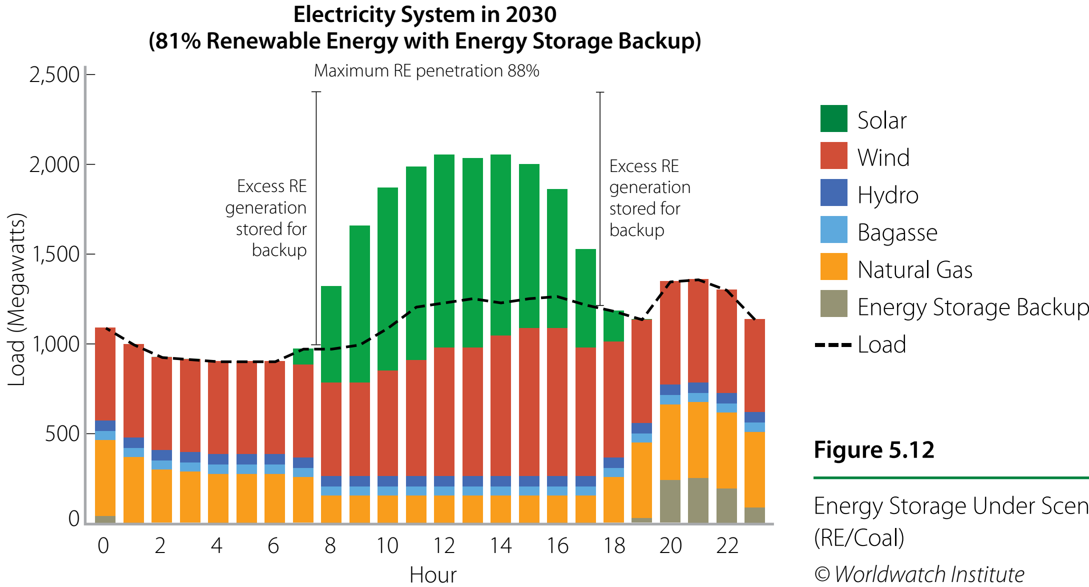

Figure 5.12

Energy Storage Under Scenario 2 (RE/Coal)

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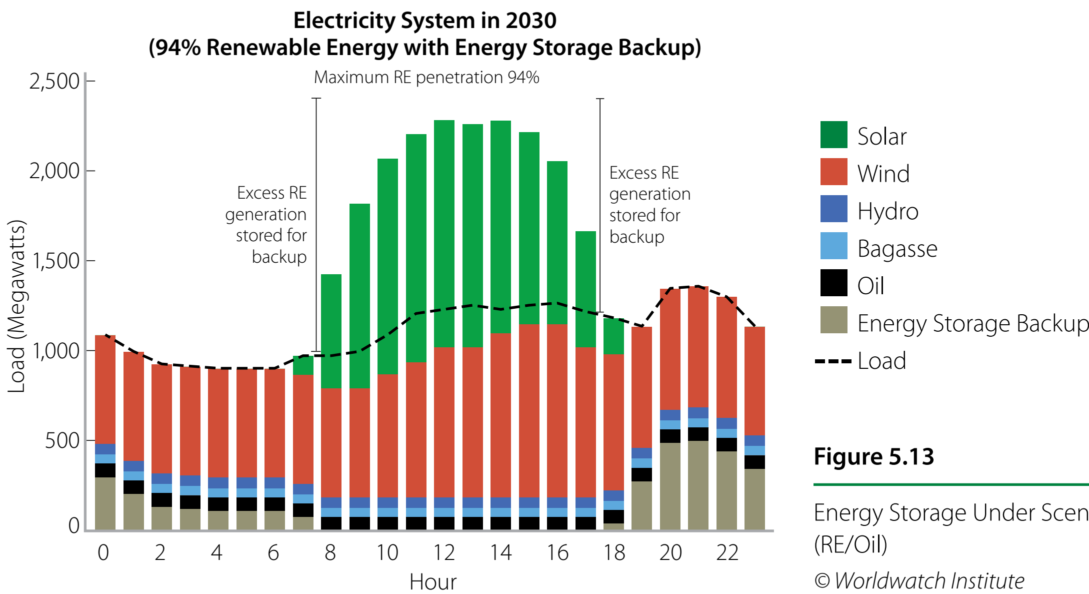

Figure 5.13

Energy Storage Under Scenario 3 (RE/Oil)

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solar generation decreases from 31% to 19%. (See Figure 5.13.) This analysis further reinforces the fact that high renewable energy penetrations on the grid require flexible generation.

Using batteries for storage in Jamaica is a technology that can be employed already today, as exemplified by one of the world's largest and oldest utility-scale battery systems, located on the island of Puerto Rico. This 20 MW lead-acid battery system was commissioned in 1994 and repowered with new batteries at a cost of USD 575 per kW in 2004. This battery system provides increased reliability to Puerto Rico's grid and supports the generation side of the grid by fulfilling rapid-reserve requirements and frequency control. The system also supports transmission and distribution services with voltage regulation, providing much more reliable service for customers.

Not only are batteries a mature technology option, but further improvements in technology and innovation are projected to substantially decrease battery costs, especially for technologies that are denser, more efficient, and have a longer lifetime than lead-acid batteries. Bloomberg New Energy Finance predicts that by 2030, the cost of lithium-ion batteries will be reduced by 90% in comparison to today, further opening new opportunities to manage a system with great renewable energy penetration. (See Figure 5.14.) Given projected price reductions, by 2030 batteries might be a cost competitive option for Jamaica to address variability and reduce curtailment at high penetrations of renewable energy.

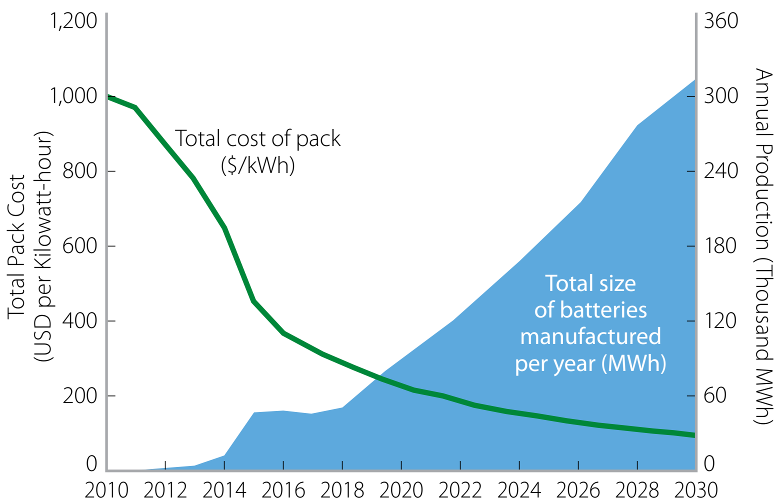

Figure 5.14

Battery Cost Projection
Note: Total pack cost includes the battery management system.
Source: Bloomberg New Energy Finance

5.6 Conclusion

This chapter has shown that a transition to a sustainable electricity sector based on expanded use of renewables is technically feasible in Jamaica. Future demand, as predicted by OUR, can be met at all times despite concerns about intermittency of wind and solar energy. Worldwatch's analysis also challenges the government's plan for tendering coal power. The construction of new coal power plants will lock in this technology for the next 40 years and reduce the capacity of the Jamaican electricity sector to integrate larger shares of renewable energy.

Natural gas and oil-based generation technologies are much more suited to accommodate expanding renewable energy use. They are flexible solutions whose production can be more quickly adjusted to the needs of intermittent resources. Electricity produced by smaller natural gas plants can be dispatched very quickly in response to demand fluctuations throughout the day. Diesel generators can be used in a similar way and provide necessary back-up power during times of low renewable energy generation.

New natural gas plants can secure electricity demand in the transitioning period, particularly if investments in renewables do not take off as quickly as needed. The use of natural gas does face challenges, however, and requires the country to find a willing LNG exporter and to build import terminals and distribution infrastructure. To date, Jamaica has been unsuccessful in securing LNG imports, as it has not been able to agree with Trinidad and Tobago—the major regional supplier—on an import price. The U.S. shale gas boom may alter the global and regional market if the United States becomes a major gas exporting country, as many experts predict.[9] U.S. LNG exports might not only be a source for Jamaica but also force Trinidad and Tobago to look for additional regional distribution opportunities given increased global competition.

Importing LNG will likely commit Jamaica to a long-term contract for a defined import amount. Although natural gas would help secure electricity demand in the next 10 years, capacity rates of gas plants are then projected to decrease in Worldwatch's scenarios with high renewable energy penetration. Jamaica will therefore likely need to find additional usage if it decides to import LNG, such as in a growing industrial sector or in transportation.

Worldwatch's scenarios also show that Jamaica does not need any new conventional power but instead can rely on an extended use of its oil-based generation technologies. This would be even more the case if demand does not increase as much as projected but stagnates further in the coming years due to slow economic growth. Although the use of oil-based generation would overcome the need to build new conventional power capacities, it does necessitate an accelerated transition to renewables. Investments in renewable energy need to be scaled up substantially in comparison to today's levels.

Overall, various technological pathways will allow Jamaica to meet its established renewable energy targets and its projected future energy demand. However, simply accomplishing both of those tasks means settling for an electricity system that falls short of the full promise of Jamaica's abundant domestic renewable resources. As shown in this chapter, Jamaica has an opportunity to lead by example and to build an electricity system that has extremely high shares of renewable energy penetration.

Achieving that energy future will not be easy, but it can be done by pursuing one of three scenarios in which a fossil fuel-based energy choice accompanies the transition—whether natural gas (achieving a 94% renewables share), coal (an 81% renewables share), or oil (a 93% renewables share). It is unclear what path Jamaica is leaning toward right now. Although plans for LNG have been prominent for some time (with talk of building a 360 MW LNG-fired plant), in the last year the government has also discussed switching to coal given the increased price of natural gas on world markets. While both options would both be useful in meeting currently stated goals, choosing coal over gas would make it more difficult to realize a truly bold and sustainable electricity system.

6 | Assessing the Socioeconomic Impacts of Alternative Electricity Pathways

Key Findings

- Jamaica's energy future lies in developing local resources to decrease its trade deficit, increase energy security, lower electricity prices, reduce emissions, and create new jobs.
- Hydro, bagasse, wind, and solar are local renewable resources that can be readily integrated into Jamaica's electricity system and decrease energy prices; these renewables have strong resource potentials, leading to costs lower than any other currently available electricity generation option on the country's grid.
- The cost for renewable energy generation in Jamaica is currently less than 9.6 U.S. cents per kWh on average, which is 42% cheaper than the least-cost fossil fuel generation option on the grid—the Bogue combined-cycle power plant—at 16.4 U.S. cents per kWh.
- By 2030, the cost of renewable energy is expected to decrease further, to an average of 6.9 U.S. cents per kWh in 2030, whereas the costs of efficient oil, natural gas, and coal-fired power plants are expected to be 22, 14, and 10 U.S. cents per kWh, respectively.
- Integrating environmental costs in these cost assessments further strengthens the argument to move away from a fossil fuel-based electricity system. Accounting for local pollution and climate change costs, a kWh generated by wind power is one-fifth the cost of one generated from oil combustion turbines and less than one-third that from diesel generators. Coal power is about 2.5 times the cost of wind power and five times that of hydropower. Small-scale solar PV is about 25 U.S. cents per kWh cheaper than oil combustion and 5 U.S. cents per kWh cheaper than oil combined-cycle generation. Large-scale solar PV is about half the price of electricity generated by coal.
- Business as usual is not a feasible energy expansion option for Jamaica. Rising future demand will increase the country's reliance on fossil fuels and make the economy increasingly susceptible to price shocks; meanwhile, already-high fossil fuel imports will place an even bigger burden on economic progress. An expansion of renewables and diversification of the energy mix, in contrast, will have many positive socioeconomic impacts.
- Transitioning to an almost entirely renewable electricity system can decrease the average cost of electricity in Jamaica by 67%, from 22 U.S. cents per kWh to 7 U.S. cents per kWh in 2030.
- Higher shares of renewables require higher investments but reduce the total cost of electricity generation. Our analysis shows that Jamaica can save up to USD 12.5 billion by investing in renewables, whereas continuing the status quo will cost the country USD 29 billion to 2030, USD 23 billion of which is fuel costs alone.
- In addition to the significant economic benefits, a transition to renewables creates social benefits from job creation and reduced greenhouse gas emissions. With higher renewable shares, Jamaica can create up to

4,000 more jobs than in the business-as-usual scenario and decrease annual emissions in the electricity sector by up to 5.2 million tons, to an estimated 0.7 million tons.

- Jamaica has a resource-based economy, as tourism and agriculture are the largest employers and contribute the most to GDP. Higher oil-based generation will increase the concentration of local pollutants in the air, hurting the agricultural sector by damaging crops and fisheries and hurting the tourism sector by exponentially increasing beach erosion.

6.1 Analysis of the Levelized Costs of Electricity Generation

6.1.1 Methodology

Comparative cost assessments of different electricity generation options should go beyond the initial investment needs of constructing different technologies; they should also include important cost drivers such as operations and maintenance as well as fuel costs. Levelized cost of electricity (LCOE) analyses are a useful tool in this regard. They represent the price, per unit of electricity, required for the investment in an electricity project to break even over its useful life.[1] Useful for energy sector planning, LCOE is an economic assessment that allows policymakers to compare—using one common measure—the costs of generation technologies that have different lifetimes, utilization rates, fuel costs, and operations and maintenance needs.[2]

To estimate the LCOE for Jamaica's power system, Worldwatch used and extended a Model for Electricity Technology Development (META) developed by the World Bank's Energy Sector Management Assistance Program (ESMAP). META is populated with common default values that are necessary inputs for estimating LCOE but also allows users to customize input data to calculate country-specific costs. Worldwatch adapted and modified the model to reflect Jamaica's project- and country-specific performance characteristics and cost parameters and extended META's time frame until 2030 to reflect the government's planning horizon. We conducted extensive in-country data gathering and drew on local conditions including the renewable energy resource assessments discussed in Chapter 3; local cost data for equipment, fuel, and labor; as well as local performance data for plant efficiencies, capacity factors, and fuel quality. Worldwatch collaborated with local partners to ensure validity of the results.

META can be a useful tool for governments. In addition to comparing the economic attractiveness of different investment projects, its results can inform policymaking by showcasing the long-term effects of different fuel-cost developments, and likely cost reductions due to technological improvements and learning effects sparked by initial support instruments. META is also helpful for energy sector planning. While it does not take an integrated energy system approach and is not an optimization model, it gives energy sector planners an accurate cost overview of different supply options that should be used along with other planning models to help policymakers and regulators make informed choices. (See Worldwatch's technical pathway assessment, Chapter 5.)

LCOE analyses are not financial assessments, however, and they exclude taxes and subsidies. Moreover, the model uses the social discount rate instead of the financial interest rate that is more relevant in investment decisions for loan-financed projects. Project-specific investment analyses therefore would require also including the costs of loans that can vary substantially depending on the project's technology and size as well as the type of investor. (See Chapter 7 for important aspects of financing renewable energy projects.)

6.1.2 LCOE Results

Figure 6.1 presents the LCOE of various renewable and non-renewable electricity generation options for Jamaica. The figure shows that when the costs of capital, operations and maintenance, and fuel are factored in, most renewable energy technologies already are competitive solutions for electricity generation. This is particularly true when renewable energy sources are compared to petroleum-based generation technologies, which currently make up 95% of Jamaica's generation system but are the most expensive supply options available.

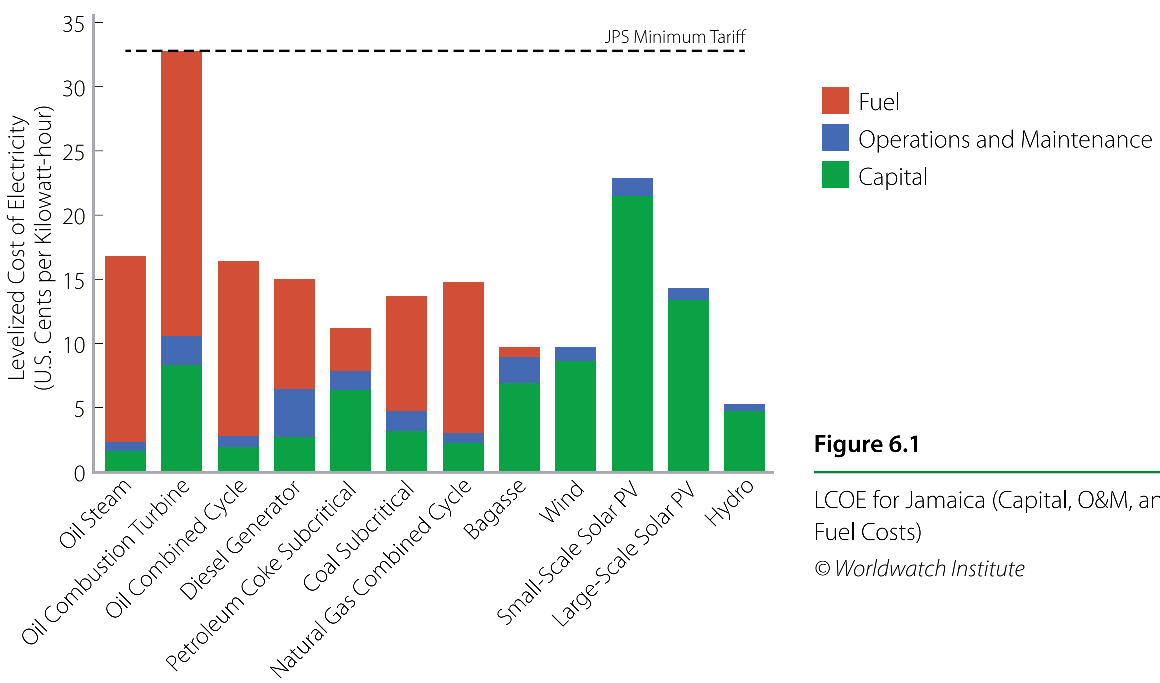

Figure 6.1

LCOE for Jamaica (Capital, O&M, and Fuel Costs)

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Hydropower is the cheapest available generation technology in the country and is less than one-third the cost of electricity produced by diesel generators, Jamaica's most common generation technology. Wind power is cheaper than all oil-based generation technologies and is highly competitive with coal or natural gas in good locations.

The costs of both small- and large-scale solar PV are currently the highest among the renewable energy sources; however, PV costs have fallen substantially in recent years. This trend is set to continue if Jamaica can take advantage of economies of scale and learning curves as it expands its PV use. (See Chapter 3.)

Electricity generation from bagasse offers another competitive renewable energy solution, although expansion is limited because of bagasse's very low utilization rate. The resource is available only during the sugarcane harvest season. An expansion of bagasse-based power is therefore constrained by the amount of sugar cane harvested each year and will not be able to exceed a production threshold of 100 MW.

Given Jamaica's great renewable energy potentials, new investments in oil-based electricity generation are not advisable from an economic perspective. Comparatively small upfront construction costs of these plants are deceiving of the high lifespan costs. Fuel expenditures drive up costs considerably, making oil-based plants uncompetitive solutions that place a burden on the country's finances. Figure 6.1 distinguishes between base costs (overnight capital costs and fixed O&M costs) and fuel costs to highlight the importance of the latter.

Of the different types of oil-based generation, oil combustion turbines are the most expensive technology, have low utilization rates, and are used only during times of peak demand. Diesel generators are cheaper options because of their greater efficiency and utilization rates. Oil steam and oil combined-cycle plants have low base costs but are comparatively inefficient.

Petroleum coke, a relatively inexpensive fuel that utilizes byproducts of oil refining, is a cheaper alternative to oil but still slightly more expensive than wind power. Petroleum coke is restricted as a generation expansion option, however, because the resource depends on the capability and the capacity of the local oil refinery to produce the fuel.

Jamaica currently does not have any natural gas- or coal-based power generation. But because the government has repeatedly considered both alternatives despite the lack of viable domestic resources, Worldwatch has included both technologies in its electricity modeling exercises to assess the impacts of their use.

Natural gas would have to be imported in its liquefied form (LNG) given Jamaica's remoteness from possible importing sources and the lack of any existing pipeline infrastructure. LNG has the benefit of being transportable over longer distances, but it requires storage and regasification facilities. In its LCOE analysis, Worldwatch assumes a price of USD 8.50 per million Btu, equivalent to OUR's initial estimates for potential imports from gas-rich Trinidad and Tobago.[3] Past negotiations between the two countries have not been able to find agreement, however, indicating that import prices were underestimated.[4] The lifetime costs of gas plants are driven largely by the price of imported gas. New suggested estimates have been in the range of USD 15 per million Btu, likely increasing Worldwatch's initial estimates seen in Figure 6.1.

Natural gas combined-cycle plants tend to be a cheaper alternative to oil-based generation because of their high efficiency and utilization rate. Even under optimistic gas price assumptions, however, natural gas is not cheaper than wind power and is almost twice as costly as an expansion of hydropower. Renewable energy sources offer a competitive alternative that could shield Jamaica from uncertain import prices and serve as a price hedge from international market price volatility.

Coal is the least expensive resource for fossil fuel-based electricity generation. Coal power generation has comparatively low fuel costs and high utilization rates. But coal, unlike natural gas, can only be used for baseload generation and must be accompanied by additional flexible generation options. As shown in the technological pathways (see Chapter 5), an expansion of coal power will impede the energy system's ability to respond to intermittency and likely limit the long-term overall share of renewable energy in Jamaica's electricity sector.

When deciding on the most cost-effective option for expanding generation, the Jamaican government should also take into account additional infrastructure costs. For example, expansion of LNG requires LNG import and distribution facilities whose costs range from USD 300 million to USD 490 million.[5] New transmission lines and substations will be needed for large-scale renewable energy projects, but the costs are manageable (see Chapter 4), and Jamaica's aging electricity grid requires repair, renovation, and upgrading anyway. Small-scale renewable generation technologies, used for distributed generation, do not need additional transmission lines, making them an attractive option for household use or communities located further from existing grid infrastructure.

6.2 LCOE+: Assessing the Full Costs of Alternative Electricity Sources

6.2.1 Methodology

The standard LCOE analysis, discussed above, offers policymakers a useful tool for energy sector planning as well as important information about which policy priorities can be developed. However, energy sector decisions should not focus on generation costs alone, but rather should reflect a more holistic assessment that includes additional costs to society—so-called externalities—such as negative health effects caused by local emissions of pollutants like particulate matter (PM), sulfur oxide (SO_x), and nitrogen oxide (NO_x).[6] This is particularly relevant for emerging or developing countries, where health care is often a luxury good and where generation technologies often lack the latest environmental control equipment.

In this report, Worldwatch has attempted to analyze the true costs of electricity generation in Jamaica, using an "LCOE+" approach to quantify some of these additional negative effects on society. To offer a more transparent measure of the costs of different generation technologies, we have added damage values in U.S. cents per kWh for the most important negative impacts, on top of the standard LCOE values calculated in Section 6.1. This allows a renewed look at the competitiveness of different technologies from a wider societal point of view.

ESMAP's META has been highly supportive in this regard because the model allows for the integration of costs caused by local pollution and climate change. Users can assign input values for the costs of carbon in USD per ton of CO_2-equivalent and for the damages caused by emissions of SO_x, NO_x, and PM, measured in USD per ton. Based on the type and quality of fuel as well as plant efficiency, the model then attaches additional costs to LCOE estimates.

Worldwatch has built on this feature to offer Jamaica a more holistic assessment of the real costs of different generation technologies, highlighting societal costs that usually are not integrated in market prices. We conducted extensive literature reviews to assign values for climate as well as pollution costs. The chosen values are explained in more detail below.

6.2.2 Costs of Local Pollutants

Local air pollutants, such as SO_x, NO_x, and PM, emitted during combustion processes, have adverse effects on human health, agricultural productivity, materials, and visibility. Already, air pollution in Jamaica is at dangerous levels, with major pollutant concentrations exceeding or nearing standards set by the National Environment and Planning Agency (NEPA).[7] (See Figure 6.2.) These pollutant concentrations reveal that

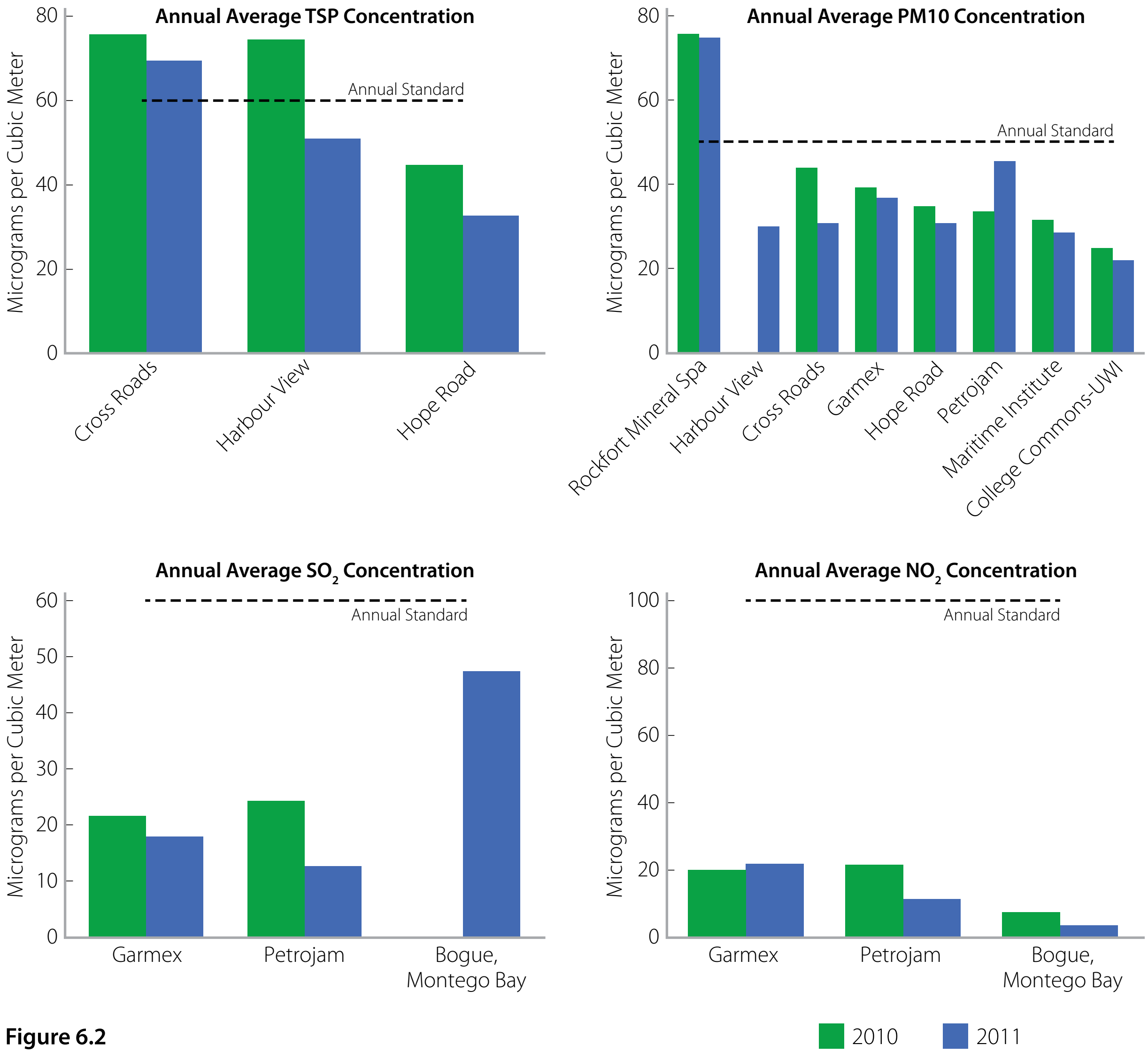

Figure 6.2

Air Pollution Levels for Stations in Kingston and St. Andrew, 2010 and 2011

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industrial facilities in the country are not adhering to international emission standards, lack adequate pollution control equipment, and are using sub-standard fuel.

NEPA data indicate that standards for total suspended particulates (TSP) have been exceeded consistently in the urban areas of Cross Roads and Harbour View. Cross Roads is a commercial neighborhood in Jamaica's largest city of Kingston, while Harbour View is located near an international airport and a major industrial area with activities such as flour milling, cement manufacturing and quarrying, oil refining, and power production. Particulate matter (PM10) concentrations have exceeded standards at the popular tourist destination of Rockfort Mineral Bath and Spa, located near Harbour View. SO_2 concentrations are nearing the NEPA standard at Bogue, which is located near a combined-cycle power plant and a wastewater treatment facility.

Jamaica's electricity sector contributes substantially to the current state of Jamaica's air quality, emitting 26% of particulates, 47% of SO_x, and 84% of NO_x emissions in 2010. Expanding fossil fuel-based generation will only increase local air pollution, further deteriorating the environment and posing an economic burden to Jamaica's most important economic sectors—tourism and agriculture.

Worldwatch's goal through LCOE+ analysis is to better illustrate environmental externalities of electricity generation that are currently not being shown in market prices. The most precise approach would be to conduct site-specific assessments that evaluate in detail factors such as the expected dispersion of pollutants from a certain plant, the increase in pollutant concentrations, and the stress on the local environment given its specific characteristics; however, these tend to be extremely cost, time, and data intensive. Nevertheless, it is possible to draw some general conclusions about pollution costs from electricity generation based on a set of key inputs such as the technology and fuel used, the age of the plant, the existence of pollution control equipment, and a country's income and population density.

Efforts to quantify and internalize the negative impacts of electricity generation reach back more than 30 years.[8] Putting a monetary value on damages has proven challenging at times: for example, the causal links between pollutant concentrations and health impacts are still being studied, creating uncertainties; attaching a certain value to human life can significantly alter the results and has tremendous ethical repercussions; and, although human life depends on the services that ecosystems provide, the benefits of specific conservation efforts are only partially measurable.

Despite these difficulties, progress has been made in several recent research projects.[9] For its estimates, Worldwatch employed a World Bank model developed specifically to evaluate the damage from pollutants in developing nations.[10] We adapted the model for Jamaica, with adjustments for income and population, and incorporated it into the LCOE to evaluate the damage costs of local pollutants per unit of energy generated.

6.2.3 Costs of Global Climate Change

In addition to releasing local pollutants, fossil fuel-based power generation is one of the biggest emitters of greenhouse gases, contributing to human-induced global warming. Global impacts of climate change include increasing temperatures, more-frequent heat waves, higher sea levels, more drought-affected areas, and increased storm intensity.[11] The severity of these impacts varies by region, but Caribbean islands are believed to be among the most vulnerable countries.[12] The most significant consequences for small-island states are likely to be related to changes in sea level, given the coastal locations of most of the economic activity, infrastructure, and population. Jamaica, like most island states, is also likely to suffer from changes in rainfall, soil moisture, and prevailing wind patterns.[13]

Carbon dioxide and all other greenhouse gases are global pollutants whose impact is independent of the point of emission. A specific point source in Jamaica such as a power plant contributes to global warming, but it cannot be made solely responsible for negative regional impacts. A ton of CO_2 emitted in Jamaica has the same negative effect on the country as a ton emitted in the United States, China, or Saudi Arabia.

Despite the global nature of climate change and the historic responsibility of industrialized countries to reduce their emissions, Jamaica's potential for emission reduction is large from a regional perspective. In

2009, Jamaica had the fourth highest CO_2 emissions intensity of 15 Caribbean nations, while having the fourth lowest GDP per capita.[14] (See Table 6.1.) By comparison, the emissions intensity of the Dominican Republic, with a similar GDP, was over 50% less.[15]

To integrate the costs of climate change into its LCOE analysis, Worldwatch assumed a global cost of carbon of USD 100 per ton of CO_2-equivalent. While at the upper-mid range of existing estimates, this value is in line with prominent economic research.[16] This cost also arguably better represents new findings about the severity of climate change's negative impacts.[17]

The inclusion of climate change costs in the Jamaican LCOE is not intended to imply that Jamaicans should cover these costs. The goal is rather to change policymakers' perception of the completeness of conventional cost assessments, to see the potential economic burden that climate change may pose to Jamaica's economy, and to heighten awareness of the opportunities that alternative energy sources bring for putting the country on a climate-compatible development path.

Table 6.1. Emissions Intensities of 15 Caribbean Countries, 2011

Country	Energy-related CO_2 Emissions	GDP per Capita	Emissions Intensity (CO_2/GDP)
	kilotons	USD	kilograms per dollar
Trinidad and Tobago	52,069	17,627	2.754
Guyana	1,672	3,258	1.563
Suriname	2,335	8,125	1.006
Jamaica	**9,557**	**5,330**	**0.851**
Antigua & Barbuda	732	12,757	0.844
The Bahamas	4,734	21,490	0.674
St. Kitts and Nevis	303	14,122	0.647
Grenada	269	7,427	0.505
Haiti	2,103	732	0.448
Belize	536	4,577	0.431
St. Lucia	425	6,755	0.421
Dominican Republic	20,640	5,486	0.417
Dominica	142	6,673	0.408
Barbados	1,442	13,076	0.375
St. Vincent and the Grenadines	199	6,320	0.318

Source: See Endnote 16 for this chapter.

6.2.4 Results

Figure 6.3 shows the LCOE with external (environmental) costs from both local air pollution (PM, SO_x, NO_x) and climate change (CO_2), comparing the results for each generation technology during operation. The data provide a pressing argument in favor of a transition toward clean energy alternatives.

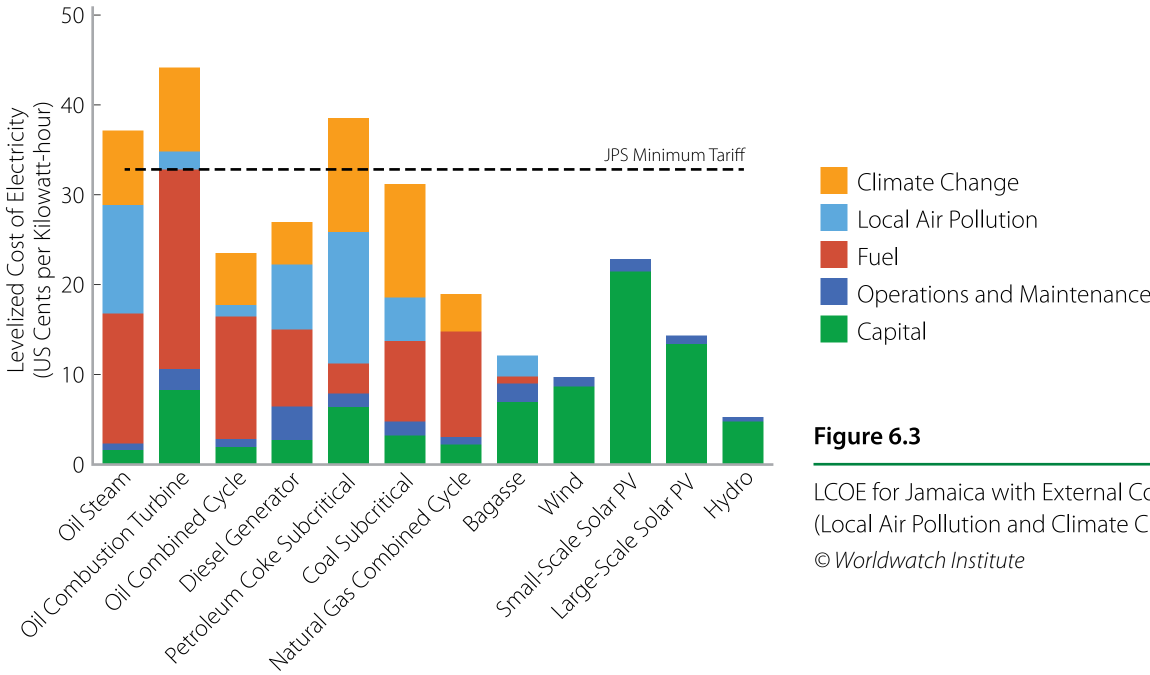

Figure 6.3

LCOE for Jamaica with External Costs (Local Air Pollution and Climate Change)

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With regard to local air pollution, oil steam generation is the most injurious to human health and the environment due to its low efficiency and its usage of heavy fuel oil, which has a high sulfur and particulate content. Diesel generation, currently Jamaica's most common generation technology, is similarly bad. Electricity generation using petroleum coke is also detrimental due to the low quality of the fuel and its high pollutant content.

From a global climate perspective, coal use is particularly carbon intensive and therefore has the greatest global warming effect. Natural gas has low pollutant concentrations and is also less carbon intensive than any of the other conventional technologies. Combined-cycle technology is the most efficient form of thermal power generation.

The LCOE+ analysis offers a new view on the competitiveness of different electricity generation sources. Coal power becomes 16 U.S. cents per kWh more expensive than its conventional estimates. That is roughly equivalent to a 200% increase. The generation cost of diesel generators is almost 34 U.S. cents per kWh, that of oil steam generation almost 42 U.S. cents per kWh, and that of oil combustion turbines more than 50 U.S. cents per kWh. Natural gas is the only conventional fuel that retains some level of competitiveness.

The cheapest generation sources, however, are wind and hydropower. Generating 1 kWh of wind power is one-fifth the generation cost of oil combustion turbines and less than one-third that of diesel generators. Generating coal power is about 2.5 times the cost of generating wind power and five times that of hydropower. Solar PV is substantially less expensive than oil-based generation and also below the cost of coal power. Large-scale solar PV is about half the price of electricity generated by coal. Bagasse-based electricity generation becomes slightly less competitive in comparison to other renewable energy sources because it causes significant local pollution.

The conclusions from this analysis change very little if only the costs of local pollution are added. Health-related pollution costs, particularly those caused by petroleum-based generation, make these technologies highly undesirable from a societal point of view.

Moreover, it should be emphasized that these findings are conservative measures. The World Bank model that we used to determine pollution costs in developing countries is not comprehensive and ignores key impacts. It evaluates only human health effects, the effects on visibility, and soiling damage to buildings. More-comprehensive studies on developed countries also evaluate the effects of local pollution on agriculture, forests, fisheries, recreation, tourism, habitat, and biodiversity.[18] Further research on pollution costs in developing countries is therefore recommended to extend the LCOE+ work.

6.3 LCOE Projection: The Future Costs of Electricity Generation

6.3.1 Methodology

Earlier chapters of this report assess the technical feasibility of transitioning to a Jamaican electricity sector based almost entirely on renewable energy by 2030. Analyzing the socioeconomic impacts of such a transformative change demands looking beyond current generation costs (see Sections 6.1 and 6.2) and assessing likely cost trends in the future. These can then be used to further analyze macroeconomic impacts such as clean energy investment needs and/or changes in fossil fuel import costs (see Section 6.4).

Although it is impossible to accurately predict future prices, analysts can make projections based on current available information and qualified assumptions. In this report, Worldwatch used its LCOE estimates as a basis from which to extrapolate cost developments for different generation technologies. We assume that future base costs for thermal and hydropower generation will remain very similar to today's levels, in line with the U.S. Department of Energy's cost database.[19] At the same time, we assume that the costs of wind and solar PV will decline further, as indicated by the International Renewable Energy Agency's (IRENA) cost analysis series.[20] And we assume that fuel prices will increase in real terms from 2010 to 2030, as projected in the U.S. Energy Information Administration's (EIA) *Annual Energy Outlook*.[21] The largest increases are seen in the price of oil.

6.3.2 Results

Based on these assumptions, Figure 6.4 projects the LCOE for various electricity generation technologies in Jamaica to 2030. By 2025, all renewable energy technologies are projected to be cheaper than fossil fuel-based power generation. Large-scale solar PV becomes cost competitive with coal and natural gas in 2015 and overtakes hydropower as the least expensive form of electricity generation in 2030. Small-scale solar PV is projected to experience the sharpest cost reductions, to be cheaper than coal and natural gas by 2025, and to be cheaper than wind by 2030. In addition, wind is projected to be cheaper than coal and natural gas by 2015. Electricity generation using bagasse cogeneration is projected to stay the same, as the technology is believed to have reached maturity.

Among fossil fuels, coal is projected to be the least expensive electricity generation option in 2030 because of abundant global reserves; however, it will not be able to compete against several lower-cost renewable energy options. Figure 6.4 also shows that a continued reliance on oil-based power generation threatens to aggravate Jamaica's worsening economic situation and will likely burden industry and households with

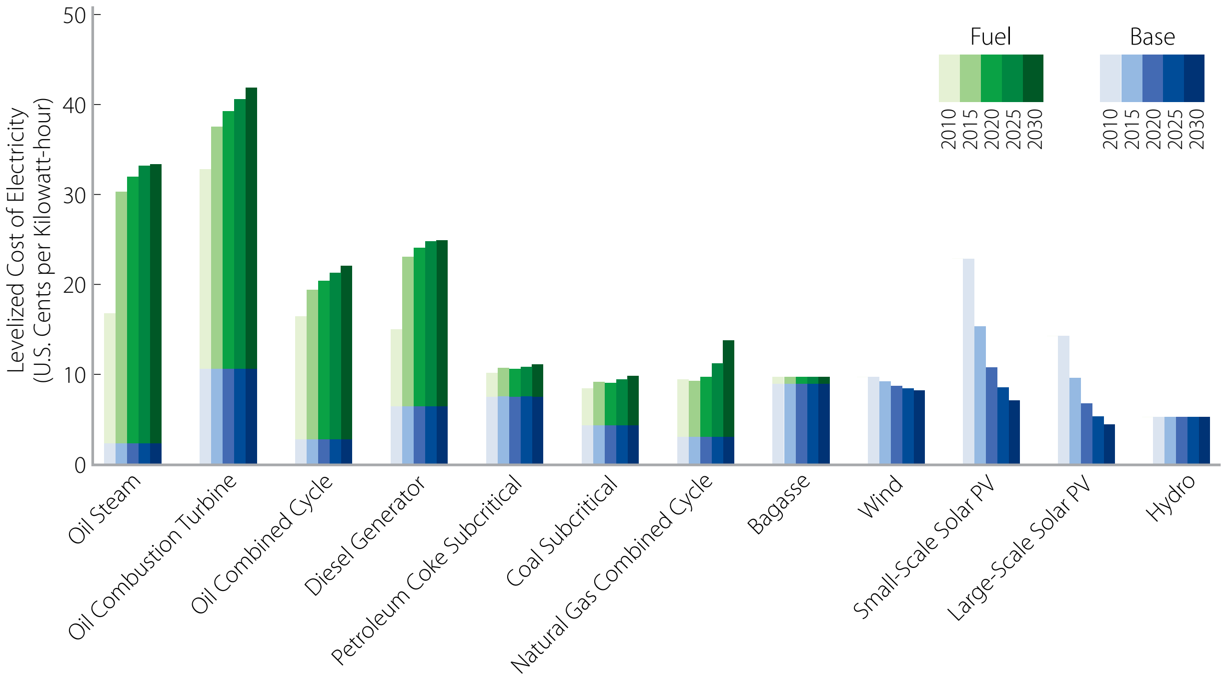


Figure 6.4

Jamaica LCOE Projection to 2030 © *Worldwatch Institute*

electricity price increases to cover growing generation costs. Oil-based generation is not currently cost competitive with any other form of electricity generation in Jamaica, nor will it be in the future.

These results are sensitive to new developments, including the development of new technologies and the discovery of new natural resources. Given currently available information, however, an expansion of renewable energy is a good price hedge against volatile and rising fossil fuel prices, and over time it becomes the most economical electricity option.

6.4 Macroeconomic Impacts: Benefits of a Transition to Renewable-Based Electricity Systems

Rebuilding an energy system based on renewable energy will have economic impacts. The following sections apply the findings from the LCOE results to the different technological pathways outlined in Chapter 5 in order to assess their potential economic impacts.

Although opponents often argue that an expansion of renewable energy poses an economic burden, the quantitative analysis done in this chapter shows the exact opposite for Jamaica: that a system based largely on renewable energy can reduce average and total costs of electricity, save the country much-needed public funds on avoided import fuel costs, and create new jobs in the energy sector.

6.4.1 Falling Costs of Electricity Generation

Electricity prices in Jamaica are high by international comparison. OUR plays a central role in determining the prices that JPS can charge its customers, using fuel costs as one of the main driving factors. A look at the development of generation costs is therefore a good proxy for possible developments of future industry and household electricity prices. Figure 6.5 shows the average LCOE in 2030 for the different Worldwatch scenarios presented in Chapter 5. The average cost of electricity was calculated using projections of LCOE estimates (see Section 6.3) as well as annual generation and utilization rates (see Chapter 5) from each generation source.

Figure 6.5 shows a clear trend: that continuation of the status quo is more expensive than any renewable expansion scenario. This is largely a result of projected rising oil prices. Moreover, as the costs of renewables are projected to decline and fall below those of conventional power, the average cost of electricity decreases with growing renewable energy penetration. Average generation costs in 2030 are projected to be below 7 U.S. cents per kWh in the scenarios with the greatest renewable energy penetration: Scenario 1 (natural gas) and Scenario 3 (oil) with renewables shares of 94% and 93%, respectively.

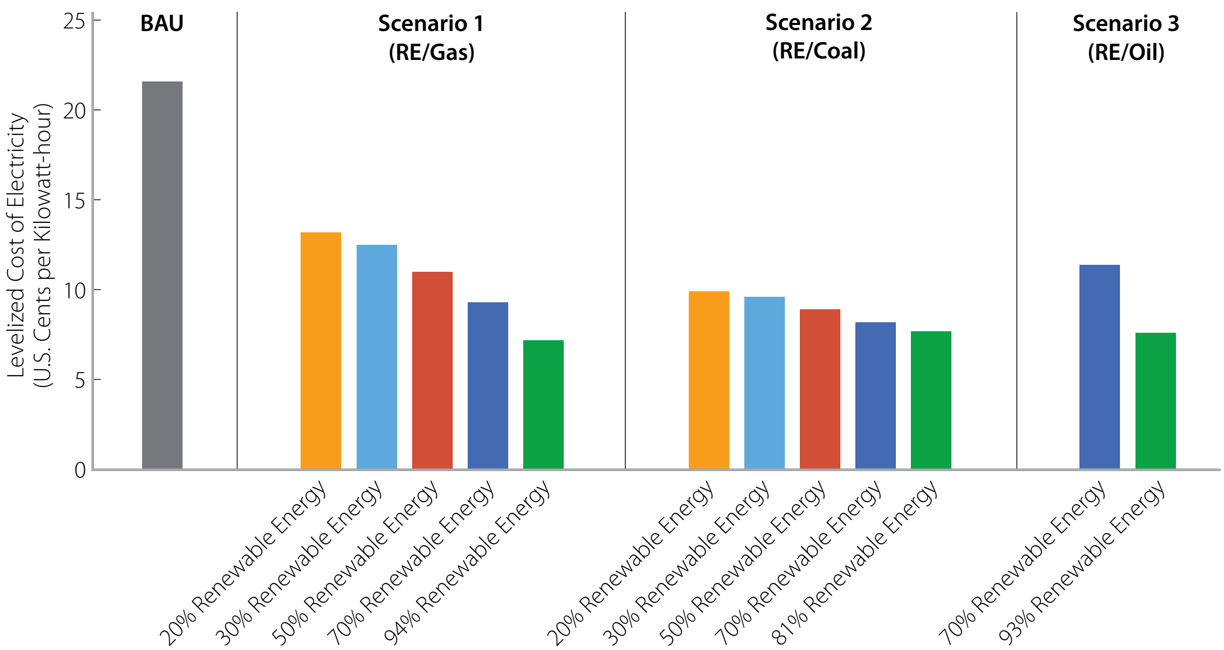


Figure 6.5

Average LCOE in 2030 Under BAU and Scenarios 1, 2, and 3 © *Worldwatch Institute*

Results for Scenario 2 (coal) show that an expansion of coal power can also have a price-dampening effect, particularly when the ambition to achieve greater renewable energy shares is lacking. As in Scenarios 1 and 3, however, the average LCOEs are lower as the share of renewables increases. Average LCOE development in Scenario 3 is highly dependent on the speed and ambition of an renewable energy expansion, more so than in Scenarios 1 and 2 where high electricity costs due to oil-based generation are already somewhat balanced out by a switch to coal or natural gas power.

The results are susceptible to fuel cost price changes, which may lead the price differentials between the scenarios to increase or decrease. Overall, however, the graphs show that an accelerated transition to renewable energy pays off. Greater shares of renewables have the potential to halve the current cost of today's electricity system, and therefore leave room for substantial tariff reductions for Jamaica's economy and population.

6.4.2 Saving Billions on Reduced Fossil Fuel Imports

Moving away from a fossil fuel-based power system can save Jamaica limited financial resources, aid economic progress, and help lower the country's trade deficit. Jamaica currently spends 12% of its GDP, or about USD 1.6 billion annually, on petroleum imports. Without reform, this figure is set to increase, further burdening Jamaica's finances and industry and decreasing the country's energy security. Growing energy demand and rising fossil fuel prices threaten to become an economic and security disaster for Jamaica.

In the BAU scenario, annual import costs for the electricity sector are set to increase from USD 0.5 billion in 2012 to USD 1.7 billion in 2030. (See Appendix VI.) A switch to renewable energy can substantially reduce this import reliance, to as low as USD 100 million annually by 2030.

Figure 6.6 shows the cumulative import costs for fossil fuels under Worldwatch's three renewable energy expansion scenarios. The graphs also show fuel cost savings of the different scenarios versus BAU. Fuel cost imports in the BAU scenario add up to USD 23 billion by 2030. A switch to renewable energy can save Jamaica up to USD 15 billion in foregone fossil fuel imports within the same time period. This savings is set to grow even further beyond the 2030 time frame assessed in this study.

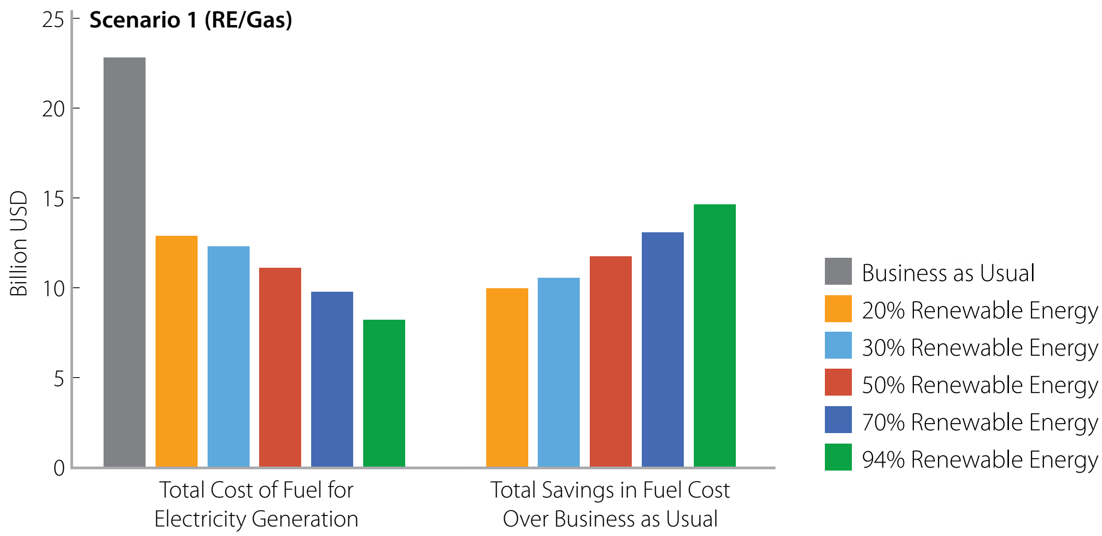
All scenarios share the result that a high share of renewable energy leads to greater overall savings. Initial investments in coal or natural gas plants that replace oil-based generation can reduce import costs. Fossil fuel cost savings are lower for Scenario 3 because the renunciation of new investments in coal or gas makes a temporary reliance on oil-based generation necessary. By 2030, however, annual import savings are among the highest of the three scenarios.

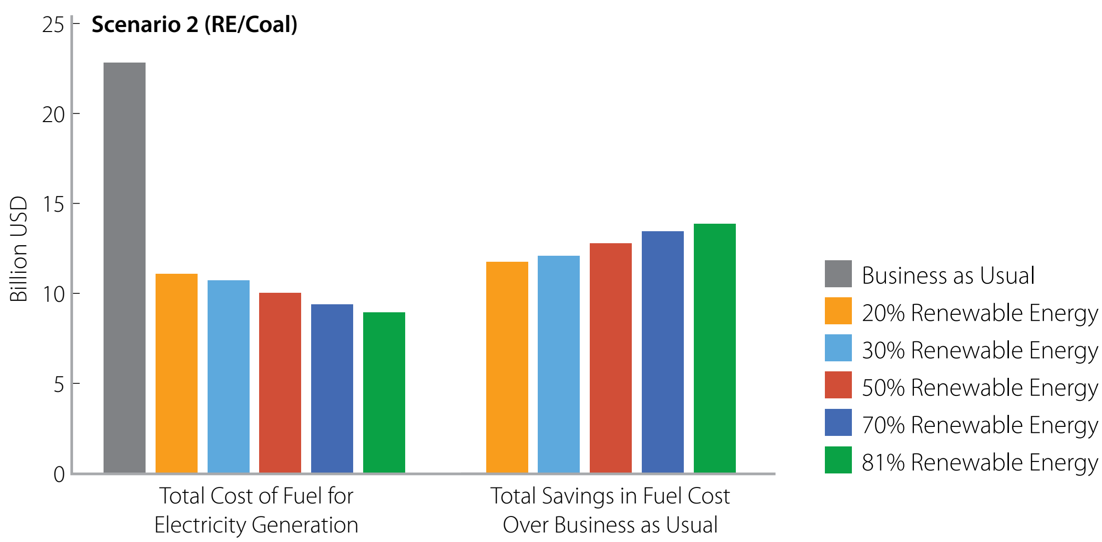
6.4.3 Investment versus Total Cost of Electricity: Upfront Costs but Long-term Savings

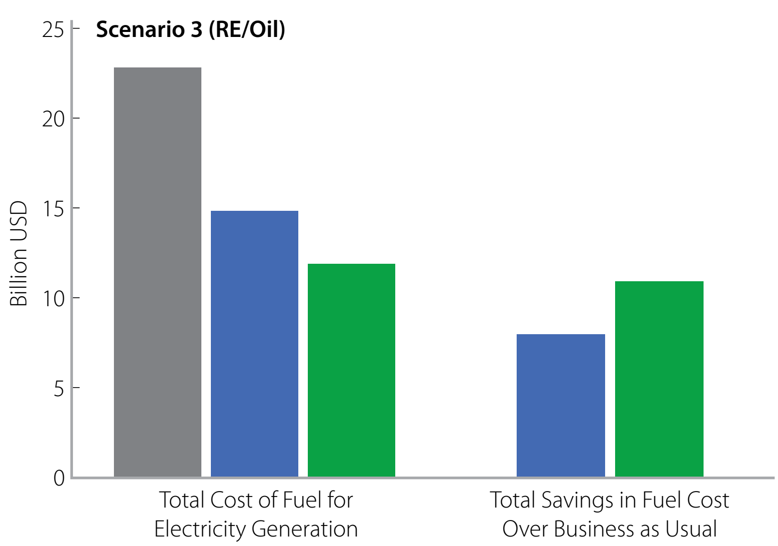
When analyzing the economics of the different technological pathways (see Chapter 5), it is useful to also compare total investment needs and total cost of electricity generation. Investment needs are a measure of the initial capital requirements to transform or modernize an energy system. Total cost of electricity generation analyses look beyond the investment needs and also take into account operations and maintenance costs, including total fuel costs. Unlike the average LCOE for given years, total cost of electricity estimates are an aggregate of electricity costs over a defined time.

Figure 6.7 shows the total investment required to meet annual energy demand in 2030 for the three scenarios. The graphs also show the total cost and savings versus the BAU scenario of electricity generation until 2030. The estimate assumes that investment includes only the overnight capital cost required to meet demand, and ignores both interest during construction and project contingencies. The cost of electricity generation comprises the total levelized cost of electricity production and therefore has the same assumptions as the LCOE analysis.

The graphs show that the BAU scenario requires the lowest investment but is the most expensive form of electricity generation due to rising oil prices. All scenarios share the result that increasing renewable







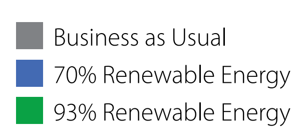
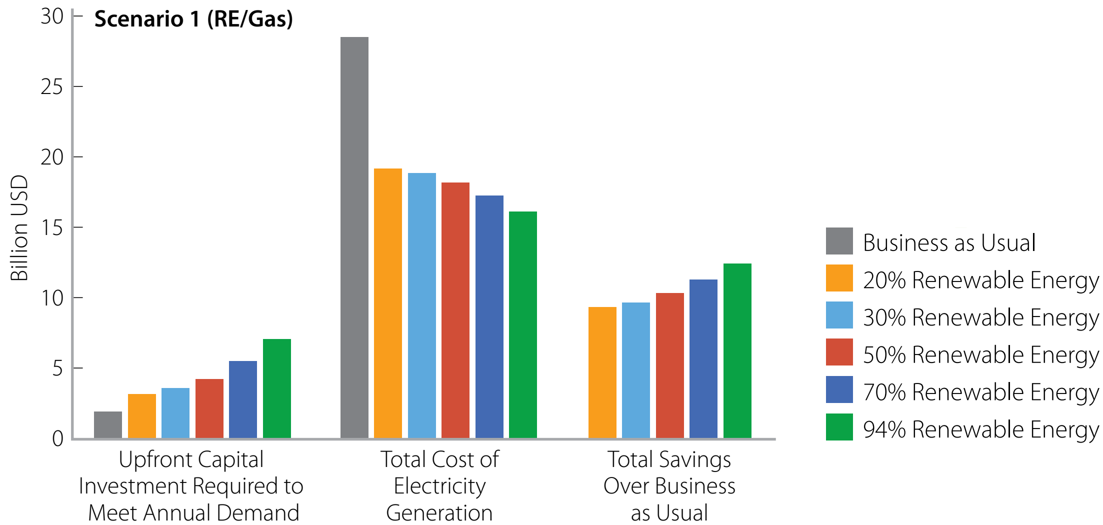
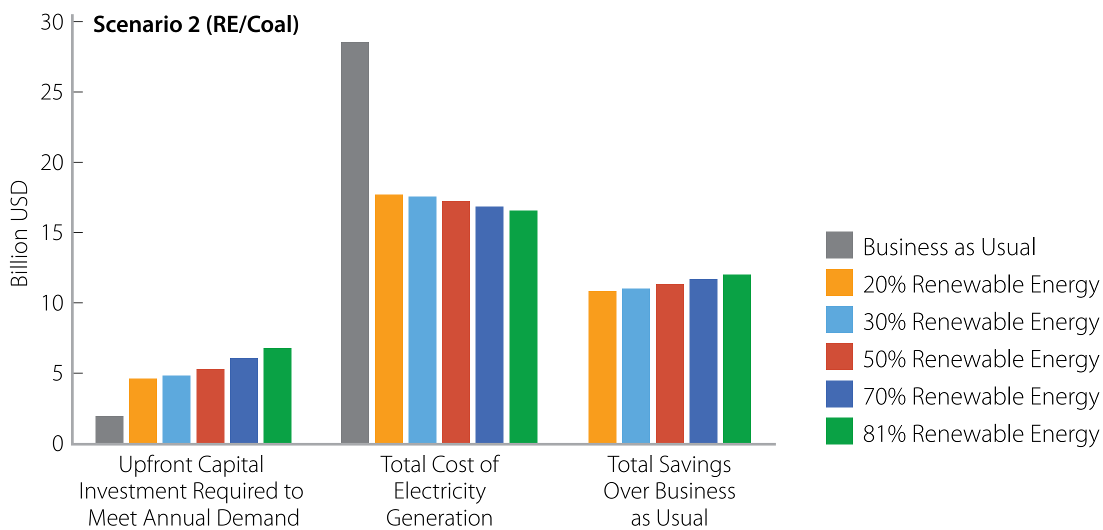


Figure 6.6

Cumulative Fuel Costs and Savings to 2030 Under Scenarios 1, 2, and 3





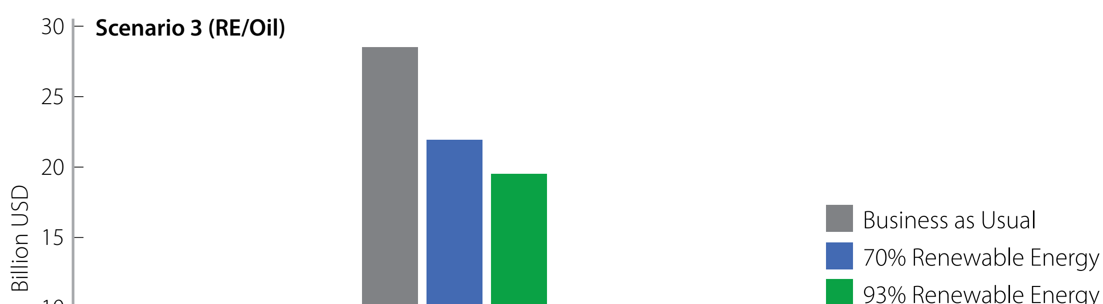


Figure 6.7

Upfront Investment, Generation Cost, and Savings to 2030 Under Scenarios 1, 2, and 3

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energy penetration requires more upfront investment, but also yields greater savings over BAU. Building up enough renewable energy capacity to power more than 90% of Jamaican electricity would cost the country about USD 6 billion. The amount is slightly higher in Scenario 1, under which new natural gas plants are built in the transition, and is slightly lower in Scenario 3 because no new conventional plants are constructed alongside an accelerated renewable energy expansion.

Implementing a largely (94%) renewable energy system with initial investment in natural gas could save Jamaica more than USD 12 billion in electricity generation costs versus BAU by 2030. Total maximum savings in Scenario 2 are slightly lower because of the limited maximum share of renewables (81%) in 2030 that is technically possible for the system to accommodate alongside coal power, despite the economic cost advantages of renewable energy by then. A transition based on the use of existing oil-based plants requires slightly less investment, potentially an enabling factor for this transition path. Total costs of electricity generation are larger, however, leading to around USD 3.5 billion less in overall savings in the long term.

6.4.4 CO_2 Emissions Savings

Meeting growing electricity demand with a continued reliance on conventional power sources will also likely increase Jamaica's climate-altering emissions. Figure 6.8 shows the projected cumulative electricity sector-related greenhouse gas emissions (CO_2, nitrous oxide, and methane) for the three Worldwatch scenarios.

Although increasing renewable energy penetration decreases emissions in all three scenarios, Scenario 3 has the greatest total emission savings versus BAU for all cases of renewable energy penetration. A transition to a renewable share of 94% of Jamaican electricity by 2030 without relying on new conventional power can save more than 45 million tons of CO_2-equivalent. With 4 million of the country's annual greenhouse gas emissions coming from electricity generation, emission savings versus BAU would therefore amount to some 11 years of current emissions from the electricity sector.[22]

Scenario 1 saves considerably more emissions than Scenario 2, as the emission factors for natural gas are much lower than those for coal. Indeed, the use of coal threatens to increase total greenhouse gas emissions versus BAU even if the share of renewable energy is expanded considerably. Investing in new coal plants would therefore put into question Jamaica's willingness to do its part in contributing to climate mitigation, likely minimizing the country's chances to qualify for international climate finance.

A common and useful tool for assessing a country's emission savings potential is the marginal abatement cost (MAC) curve originally developed by McKinsey & Company.[23] MAC curves provide a quantitative comparison of the effectiveness of different methods for reducing emissions in various regions and sectors, using both technologies available today and those that are poised to achieve maturation by 2030. A cost curve is a logical conclusion to our discussion of scenarios as it ties together the various metrics discussed in this chapter. Arriving at a cost curve requires estimates of emissions from the BAU scenario, the identification of emissions reduction opportunities, and estimates of the costs and potential abatement volume of each opportunity.

Emissions from the BAU baseline scenario were calculated using the projected base growth rate of electricity generation (discussed in Chapter 5) and assumed that current trends in the electricity mix

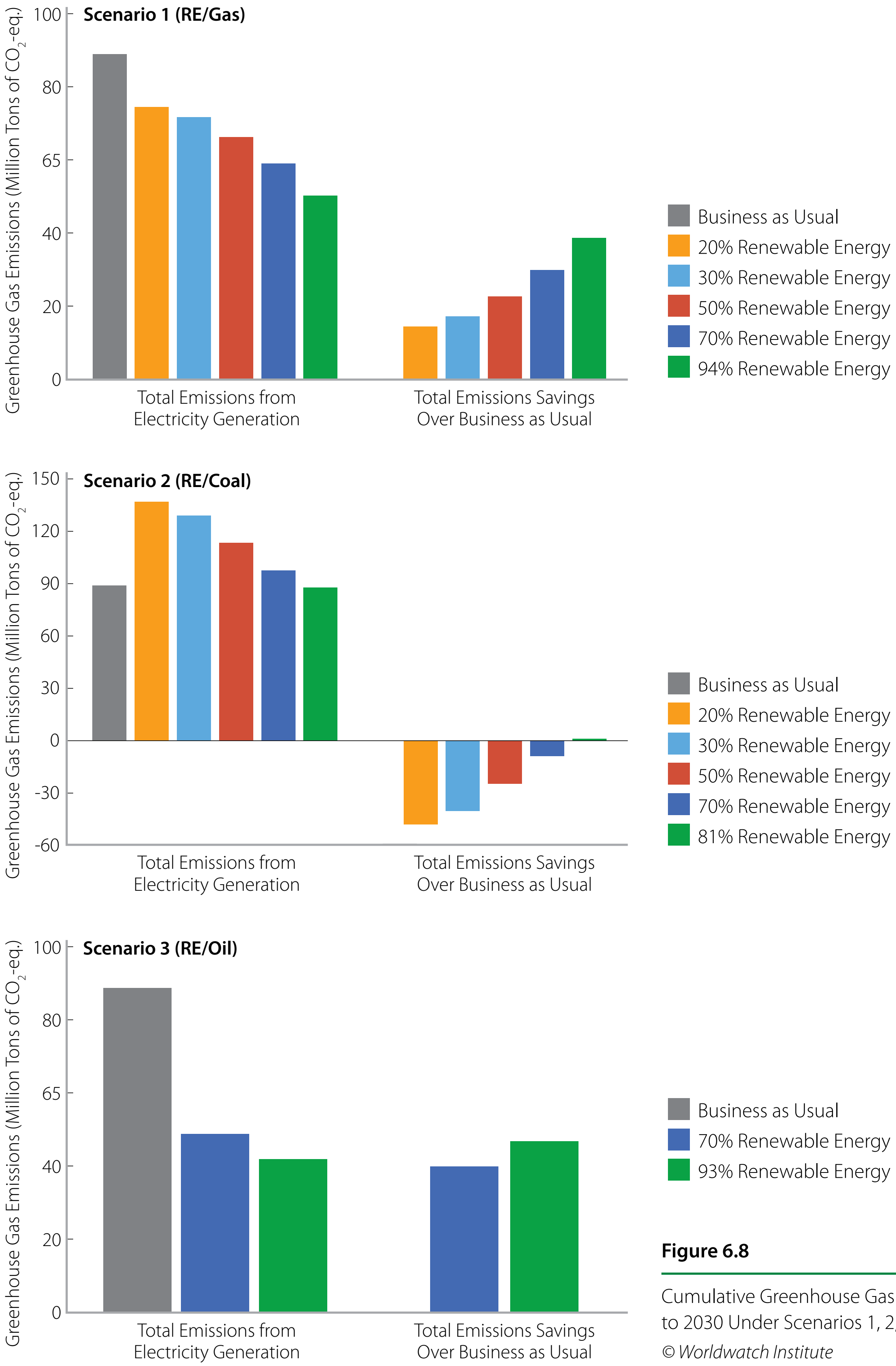

Figure 6.8

Cumulative Greenhouse Gas Emissions to 2030 Under Scenarios 1, 2, and 3

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remain unchanged. Based on these variables, Jamaica's emissions are projected to grow significantly by 2030, reaching 10 million tons of CO_2-equivalent, or 140% above 2010 levels.

Key emissions reduction opportunities in the electricity sector arise in the areas of hydropower, wind, and solar power. Improving end-use energy efficiency is also a cost-efficient abatement option, but because this assumption was built into electricity demand projections, leading to lower per capita consumption in 2030, it was not considered in this analysis.

The abatement cost and potential for each opportunity were analyzed as the final step to building the cost curve. Abatement cost is defined as the incremental cost to society of pursuing the identified opportunity compared to the cost of the action that otherwise would occur in the BAU scenario, which in our analysis was additional oil-fired generation capacity. Abatement costs are assessed from an economic perspective, not a financial one, and hence were calculated using the LCOE analysis completed in this section. The abatement potential was measured for each opportunity as the emissions avoided from oil-fired generation for the capacity replaced.

The abatement cost curve represents the available methods (levers) for greenhouse gas abatement, the abatement potential, and the corresponding costs of each lever.[24] The width of each lever represents the potential to decrease emissions, while the height represents the costs of avoiding a metric ton of equivalent CO_2 emissions from that method in the year of investigation.

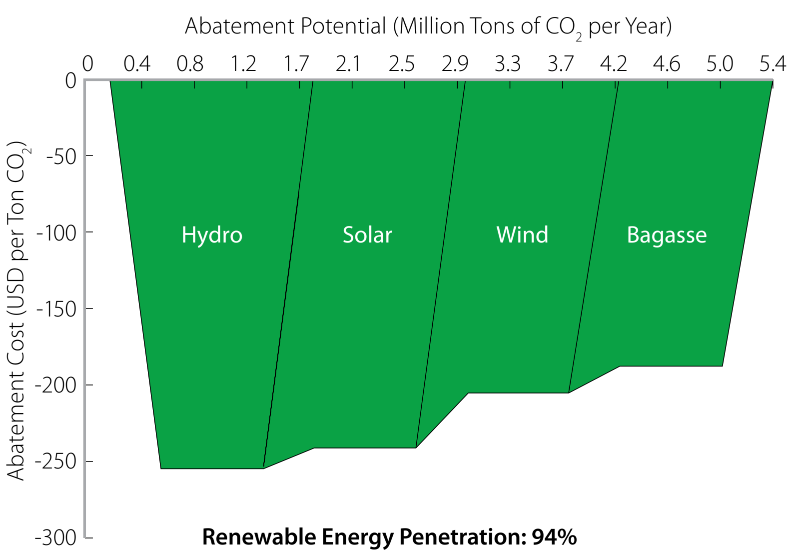

Figure 6.9

Marginal Greenhouse Gas Abatement Cost Curve for 2030

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Figure 6.9 shows the marginal abatement cost curve for the Worldwatch scenarios. It demonstrates that increasing renewable energy penetration increases the total abatement potential. The cost curve also shows that abatement options for Jamaica have negative costs, implying that it pays to decrease emissions. As was discussed in Section 6.3.2, renewables are projected to be the least-cost electricity generation options for Jamaica, which results in negative abatement costs.

6.4.5 Job Creation

A tangible economic benefit from investment in renewable energy is new job creation. New jobs can include direct jobs in the energy sector's core activities, indirect jobs in sectors that supply the energy industry, and induced jobs that are created when wealth generated by the energy industry is spent in other sectors of the economy.[25]

Direct jobs in electricity generation projects are generally divided into two categories: construction, installation, and manufacturing (CIM); and operations and maintenance (O&M).[26] (See Figure 6.10.) CIM jobs typically are concentrated in the first few years of setting up an energy facility, whereas most O&M jobs exist for the lifespan of the installation. To estimate long-term job creation, CIM jobs can be averaged out over the expected lifetime of new projects. In general, renewable power plants are more labor intensive than oil-fired power plants.[27] (See Figure 6.11.)

When available, employment data for existing and planned renewable energy projects in Jamaica can provide country-specific job creation potential estimates.[28] (See Table 6.2.) These figures are typically higher than the global estimates, which are based largely on labor statistics in Europe and the United

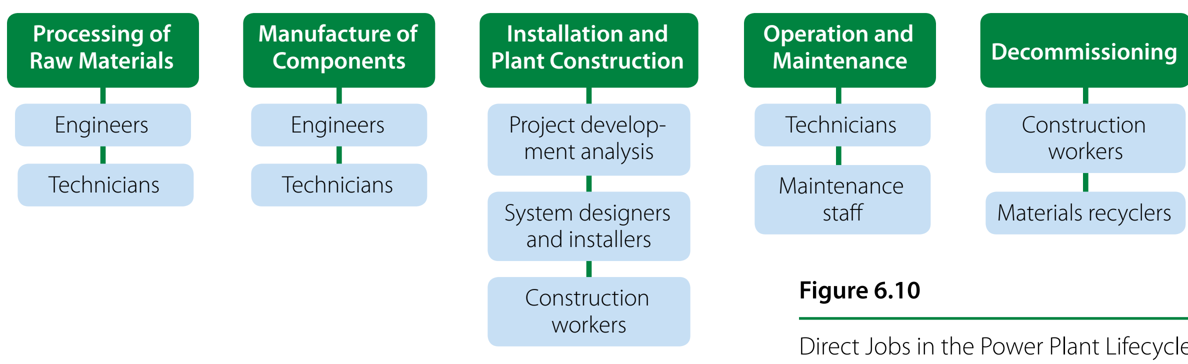

Figure 6.10

Direct Jobs in the Power Plant Lifecycle Value Chain

Source: IRENA

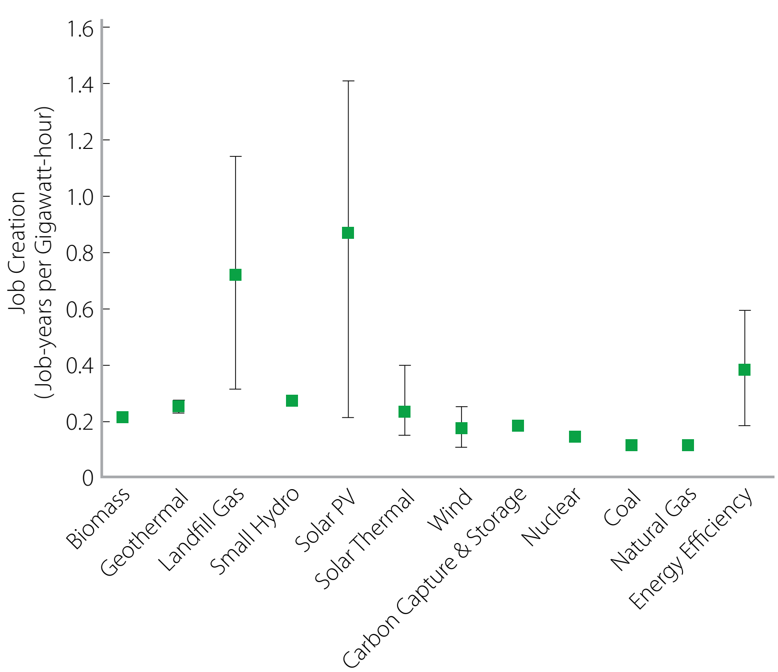

Figure 6.11

Global Job Creation Estimates for Various Power Generation Sources

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Table 6.2. Job Creation from Renewable Energy Facilities in Jamaica

Facility	Capacity	Construction & Installation Jobs	Construction Jobs per MW	O&M Jobs	O&M Jobs per MW
Wigton Phase I (wind)	20.7 MW			4*	0.19
Wigton Phase II (wind)	18 MW	70–80	4	2[†]	0.11
Wigton overall (wind)	38.7 MW				2
Residential solar PV	3 kW; installations added on a regular basis	3–5 for installation; 2–3 full-time jobs	—	Self-maintained (systems are leased)	—
Waste-to-energy	21 MW	200	9.52	100	4.76

** This includes three engineers and one technician. Wigton Phase I also employs consultants, several workers for environmental maintenance, and a couple of workers for office maintenance.*
[†] Technicians only.
Source: See Endnote 28 for this chapter.

Table 6.3. Energy Efficiency Job Training Programs in Jamaica

Program	Individuals Trained
Energy Service Company (ESCo) Industry Project for Jamaica	250
Certified Energy Managers	25

Source: See Endnote 28 for this chapter.

States. Existing energy efficiency training programs in Jamaica demonstrate the job creation potential of expanding efficiency measures in the country.[29] (See Table 6.3.)

For reference, in Bangladesh, a small developing country with limited financial resources, the not-for-profit company Grameen Shakti has installed more than 100,000 solar home systems since 1996 and aims to reach 1 million households by 2015. So far, the program has employed 660 women for installing, repairing, and maintaining the PV systems, and has trained over 600 local youth as certified technicians. Grameen Shakti aims to create 100,000 jobs through renewable energy and related businesses.[30]

In addition to the job creation estimates based on Jamaica's renewable energy potential, JPS estimates that its 360 MW of LNG capacity will create 1,200 jobs—400 skilled and 800 unskilled—during the construction phase of the power plants.[31]

Energy facilities also create indirect and induced employment. Indirect jobs are positions created throughout the supply chain based on the increased demand for materials and components required for renewable energy equipment. Induced jobs are the jobs created as the salaries earned in the direct and indirect jobs in the renewable value chains are then spent on a range of goods and services in the wider economy. The increased spending from the renewables jobs creates and supports induced jobs. In addition, reliable and affordable access to energy allows for investments in new local businesses, which bring additional revenue, income, and jobs.

Job Creation Estimates and LCOE

Figure 6.12 provides a comparison of job creation estimates with the levelized cost of electricity (LCOE). Solar PV is currently an expensive generation option but has the potential to create the highest number of jobs. Coal and natural gas, in addition to creating the lowest employment, are expensive electricity generation options, while wind and hydropower are less expensive than coal and natural gas and can create more jobs. Biomass has the potential to create more jobs than either coal or natural gas, and although it is one of the most expensive generation options, it is also viewed as a viable option to increase electricity supply through domestic sources.

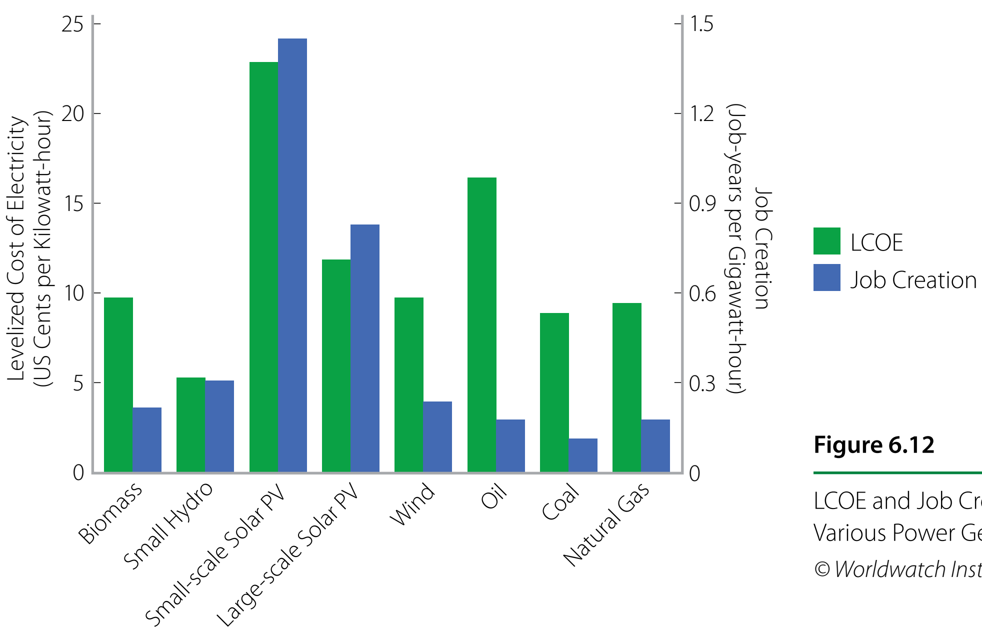

Figure 6.12

LCOE and Job Creation Estimates for Various Power Generation Sources

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Model Methodology

To assess the economic impact of various levels of renewable electricity penetration in Jamaica, we estimated the number of jobs created. To do this, we used electricity supply and demand forecasts (see Chapter 5) to specify electricity supply options for various levels of renewable penetration. We then used an economic model to estimate the number of jobs created according to the electricity demand and composition of the generation mix. Wei, Patadia, and Kammen (WPK) have built a simple but thorough methodology to forecast job creation from a specified generation mix.[32] The model is derived from a meta-analysis of 15 job creation studies, which report employment within a specific energy sector using a top-down or bottom-up approach. From this meta-analysis, the model produces direct job multipliers per unit of energy that can be applied to an electricity scenario with a specified generation mix.

It is important to note that assumptions in the WPK model can lead to uncertainties in job creation estimates. Because the model assumes that transmission and distribution are unconstrained, job impacts from developing transmission lines and pipelines are not captured. Import leakage can lead to decreased local employment but is not considered in the model. In addition, technology or product improvements can lead to lower job requirements but are not accounted for in the model.

We applied the WPK model to the three electricity scenarios elaborated in Chapter 5 to determine the cumulative number of local jobs created by 2030 in each scenario. (See Figure 6.13.) Local jobs are defined as employment that occurs within the boundaries of Jamaica. The BAU scenario creates the lowest level of employment because the current electricity system is not labor intensive. As the penetration of renewable energy in the electricity system increases, the level of employment rises with the increasing use of labor-intensive technologies. In total, Jamaica has the opportunity to create more than 4,500 new jobs in the electricity sector.

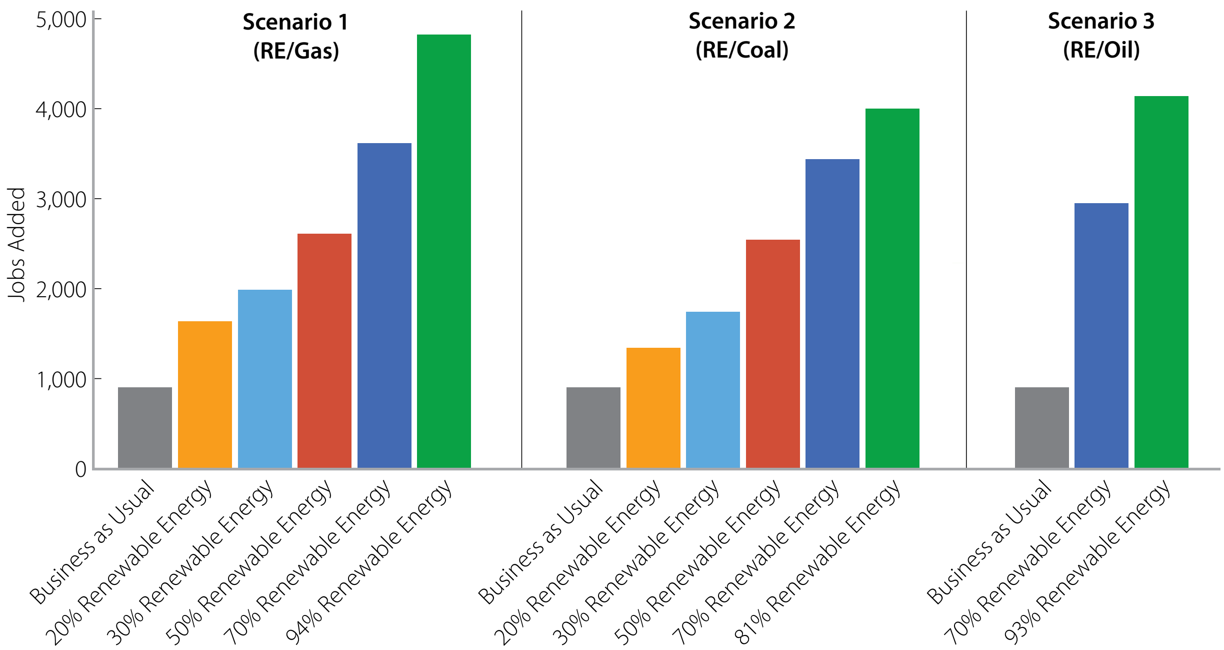


Figure 6.13

Total Jobs Created by 2030 Under Scenarios 1, 2, and 3 © *Worldwatch Institute*

Currently, Jamaica's electricity and water sectors contribute 3.1% to GDP but employ only 0.74% of the workforce.[33] In total, the two sectors employ 8,100 people. As Figure 6.13 demonstrates, however, increasing the penetration of renewables in the electricity sector can raise employment levels by over 50% in the sector. With a 13.7% unemployment rate, these are valuable job additions that come at no additional cost.[34]

Renewable energy development therefore offers Jamaica promising employment opportunities and an alternative to transferring its wealth out of the country to pay for fossil fuel imports. It is important to note, however, that most of the initial local jobs from renewables will occur in installation and O&M, since these positions are located in-country.

To capture even greater employment opportunities from renewable energy, Jamaica would need to invest in capacity building, including expanding its domestic manufacturing base to allow for production of renewable energy equipment and training a skilled labor force to install, operate, and maintain the new facilities. Stakeholders within Jamaica differ in their opinions about the feasibility of manufacturing renewable energy equipment within the country. The success of Barbados in manufacturing solar water heaters for domestic consumption and export throughout the Caribbean is cited as a success story that Jamaica could emulate, especially because of the relatively simple process for manufacturing the systems. Manufacturing and assembly of small wind turbines is another potential opportunity in Jamaica.[35]

Other stakeholders in Jamaica's renewable energy market, however, maintain that the country does not have the economies of scale or necessary capital investment needed for renewable energy equipment manufacturing or assembling. Again, the Barbados experience serves as an example: the solar water heating systems manufactured there are targeted toward a low-end, cheap residential market.[36]

6.4.6 Impact on Economic Sectors

Further research should be undertaken to understand the economic risk of local pollution and a changing climate for Jamaica's different economic sectors. Such an assessment is beyond the scope of this study but would be very insightful given the country's vulnerability to environmental disasters and its reliance on tourism as a leading industry.

The impacts of pollution and climate change in Jamaica will likely be higher than is discussed in this chapter. This is primarily because Jamaica is an environmentally at-risk island nation: the Environmental Vulnerability Index ranks it as "extremely vulnerable" because of its susceptibility to various hazards, including meteorological events, geological events, human-caused events, climate change, and sea-level rise.[37]

6.4.7 Gender Impacts

In most countries, energy-related issues are a male-dominated field because traditional gender roles tend to exclude women from technical training, investment decisions, and energy planning.[38] Limited data are available on gender and energy concerns in Jamaica, but key barriers to gender equality are common globally and can be examined in the Jamaican context.[39] Even in Jamaica, where most households have access to electricity and modern cooking fuels (the lack of which often exacerbates gender inequalities), women are still sidelined from energy-related decision making.

6.5 Conclusions

The economic case in favor of a transition to an electricity system in Jamaica based on renewable energy is pressing. It offers the country a chance to reduce surging electricity prices, save scarce resources on fossil fuel imports, decrease its trade deficit, increase energy security, and reduce greenhouse gas emissions and local pollution at negative costs.

Hydropower and wind power are competitive generation solutions already today, and solar energy will, over time, become the cheapest electricity source by 2030 if Jamaica can make use of learning effects and economies of scale. Renewables in the country already cost on average less than 9.6 U.S. cents per kWh, or 42% cheaper than the least-cost fossil fuel generation option currently on the grid. By 2030, the cost of renewables is projected to drop further, to an average of 6.9 U.S. cents per kWh.

In this chapter, Worldwatch also sought to assess the rising environmental costs from electricity generation, thinking in new paradigms that make the societal costs of electricity generation more transparent. Once local pollution and climate change costs are accounted for, a kWh generated by wind power is one-fifth the generation cost of oil combustion turbines and less than one-third that of diesel generators. Coal power is about 2.5 times the generation cost of wind power and five times that of hydropower. Small-scale solar PV is about 25 U.S. cents per kWh cheaper than oil combustion and 5 U.S. cents per kWh cheaper than oil combined-cycle generation. Large-scale solar PV is about half the price of electricity generated by coal.

Given these powerful arguments in favor of a transition to renewables, a continued reliance on fossil fuels would equate to an economic disaster. The Government of Jamaica therefore should be encouraged to develop a more ambitious plan to rebuild the country's electricity sector based on renewable energy.

An assessment of the comparative macroeconomic benefits of Worldwatch's different scenarios to a more sustainable electricity sector further underlines this importance. Transitioning to an electricity system powered almost exclusively by renewables can decrease the average cost of electricity by 67% by 2030 in comparison to 2010. A transition can also create up to 4,000 new additional jobs and decrease greenhouse gas emissions in the electricity sector to a mere 0.7 million tons of CO_2-equivalent annually. Although an accelerated expansion of renewables requires higher upfront investments, it reduces the total cost of electricity generation and can save the country up to USD 12.5 billion by 2030, freeing up public money to be spent on more pressing social and economic concerns.

All three Worldwatch scenarios conclude that a greater share of renewable energy in Jamaica's power generation mix is economically beneficial. Continued reliance on oil-based generation requires slightly less upfront investment but leads to substantially higher fuel costs and overall generation costs during the transition period. A decision not to build any new conventional power plants can secure the greatest greenhouse gas emission savings. Investments in new coal power, meanwhile, do not bring emission reductions compared with the BAU scenario, and put into question Jamaica's opportunities to qualify for multilateral and/or bilateral climate finance. The macroeconomic benefits of using natural gas as a transition fuel appear to be favorable in Worldwatch's scenarios; however, these do not include the costs of building the necessary import and distribution infrastructure, and they depend heavily on the price of LNG imports.

7 | Sustainable Energy Finance in Jamaica: Barriers and Innovations

Key Findings

- High interest rates and the lack of long-term loans pose a major barrier for financing sustainable energy projects.
- Despite high levels of external debt, interest rates in Jamaica have fallen significantly, and the country renegotiated its agreement with the International Monetary Fund in 2013.
- Several energy credit lines disbursed through the Development Bank of Jamaica provide low-interest loans for sustainable energy projects, especially for small and medium-sized enterprises.
- The ability of domestic financial institutions to provide loans for energy efficiency and renewable energy is strengthening as banks become more familiar with Jamaica's growing renewable energy market.
- The risk perception of sustainable energy investments, as well as remaining capacity building needs, are a continuing impediment to widespread domestic financing.
- Private international finance institutions continue to view Jamaica's sustainable energy market as risky; mechanisms such as loan guarantees can provide a more stable investment climate.
- Traditional development assistance from bilateral and multilateral agencies is increasingly targeted toward sustainable energy; Jamaica can harness these resources to establish energy efficiency and renewable energy programs.
- Climate financing, including through Nationally Appropriate Mitigation Actions (NAMAs), has the potential to provide major support for Jamaica's sustainable energy transition.
- Although there are various ways to promote sustainable energy through financial institutions, many investment barriers can be addressed most effectively through policy and regulatory mechanisms (see Chapter 8).

The LCOE and scenario analyses in Chapter 6 demonstrate the cost savings that Jamaica can achieve in the medium to long term by transitioning to renewable energy. The modeling results show that reaching 93% renewable electricity generation by 2030 would require less than USD 6 billion in investment from 2013 to 2030. Because of the high upfront investment requirements of renewable energy, however, access to long-term, low-interest loans is essential to capture these benefits. Sustainable energy markets are still emerging in most countries, and large conventional fossil fuel plants typically receive cheaper loans than renewable energy projects, further skewing the investment climate. Until recently, sustainable energy financing was scarce in Jamaica, although more favorable financing schemes have emerged in recent years.

High interest rates pose a barrier to accessing finance in Jamaica in general, and can significantly increase the lifetime financing expense of energy efficiency and renewable energy projects with high upfront capital costs. In addition, sustainable energy financing remains a relatively new market in Jamaica, so banks are still building their lending capacity, and project developers often lack experience in obtaining loans and permits. In many cases, interest rates are the make-or-break factor in determining the viability of renewable energy projects: over a 10-year loan period, increasing the interest rate from 5% to 20% can nearly double financing costs.[1] (See Figure 7.1.)

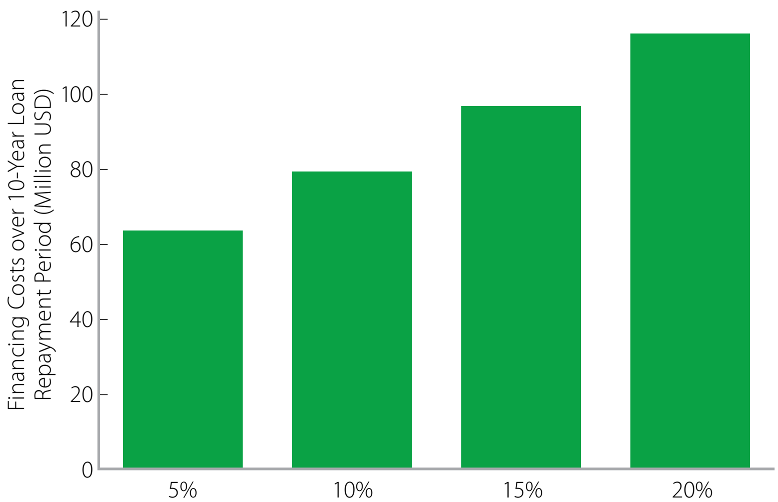


Figure 7.1

Impact of Interest Rates on Financing Costs for a Utility-Scale Wind Farm

Note: Assumes a 10-year, USD 50 million loan.
© Worldwatch Institute

Certain economic sectors do have reliable access to financing, however. The private sector in Jamaica has strong cash flows: for example, Jamaica is the primary profit center of ScotiaBank in the Caribbean.[2] In particular, access to financing should not pose a barrier to energy efficiency and renewable energy investment in the hotel and tourism industry, where the necessary funds often are available. In cases such as this, the lack of sustainable energy investment is more a matter of the need for education about the benefits and the will to implement energy upgrades.[3]

Ultimately, many of the barriers to sustainable energy financing are the result of skewed incentives for fossil fuel energy and bureaucratic hurdles for renewable energy projects, most of which can be overcome only through policy and regulatory mechanisms. These policy solutions are examined in detail in Chapter 8.

7.1 Strengthening Capacity of Domestic Financial Institutions

Identifying existing loan packages and funds—from both domestic and international financing institutions—is an important first step toward determining the financial viability of an energy investment in Jamaica. To date, private sources of financing have proven insufficient to enabling widespread investments in sustainable energy. In addition to supplementing private capital, public financing is essential for mobilizing additional private finance by demonstrating confidence in and the viability of these projects. The effectiveness of public finance at achieving this goal is a key determinant of the future vitality of a sustainable energy investment climate.

Jamaica's debt burden poses a barrier to providing low-interest loans and accessing international finance. Jamaica is the world's eighth most-indebted country, with the total debt burden equal to 126% of GDP in 2011.[4] Jamaica's most recent 27-month, USD 1.27 billion stand-by loan agreement with the International Monetary Fund (IMF), which aimed to help the country reduce this debt burden and recover from the global recession, expired in May 2012. Prior to its expiration, the agreement had effectively lapsed because Jamaica's outgoing government failed to meet the terms.[5] In May 2013, Jamaica reached a new deal with the IMF through 2016–17 that will provide nearly USD 1 billion in loans, USD 200 million of which was disbursed to the country immediately.[6]

The last IMF agreement required the Jamaican government to reduce public sector spending and increase tax revenues, potentially endangering the government's ability to provide renewable energy incentives. Under the discretionary tax waiver system, however, the government was still able to eliminate taxes and duties for the 2011 Wigton Windfarm expansion.[7] The current IMF deal highlights the importance of energy diversification, including from renewable energy, and acknowledges existing government programs to expand renewable capacity.

Most private financial institutions in Jamaica have limited experience with energy efficiency and renewable energy financing. Interest rates in Jamaica are high for loans of any kind, but they can be especially prohibitive when it comes to financing renewable energy projects. Nevertheless, the capacity and willingness of commercial banks to engage in energy efficiency and renewable energy lending has improved greatly in recent years, to the point where all the major banks now have advertisements promoting energy loans. Commercial banks in Jamaica are cash-rich and are actively seeking out assets to finance, creating a strong opportunity for scaling up energy efficiency and renewable energy investment.[8]

In addition, market interest rates have decreased dramatically, enabling banks to bring down lending rates for energy investments.[9] The weighted average of commercial bank interest rates for commercial credit in Jamaica declined from nearly 19% at the start of 2009 to just over 13% at the end of 2012.[10]

Additional capacity building for both banks and project developers, as well as financial support mechanisms, are needed to continue these improvements and enable widespread domestic lending for sustainable energy investments, and to ensure that overall interest rate reductions are applied to sustainable energy financing. Furthermore, expansion of low-interest sustainable energy loans available in Jamaican dollars would help protect project developers from currency inflation risks.[11]

7.1.1 Sustainable Energy Credit Lines in Jamaica: Progress and Barriers

The Development Bank of Jamaica (DBJ) manages several credit lines aimed at increasing the capacity of private banks to make loans for energy efficiency and renewable energy projects.[12] (See Table 7.1.) These loans are disbursed to individuals and businesses through approved financial institutions (AFIs), including commercial banks, credit unions, and microfinance institutions. For the most part, DBJ energy credit lines are aimed at small- and medium-scale investments, although some programs can support larger-scale renewable energy projects.

Loans through DBJ cover up to 90% of project costs for small and medium-sized enterprises, and up to 70% for large companies. Energy audits are required for all loans through DBJ regular funds or

Table 7.1. DBJ Energy Efficiency and Renewable Energy Credit Lines

Credit Line	Total Fund Amount	Maximum Loan Amount	Interest Rate	Repayment Period
PetroCaribe Energy Fund	Varies between J$500 million and J$1 billion (USD 6–12 million)	J$30 million (USD 340,000)	5% rate charged to AFIs; 8% maximum rate to borrower (on the Jamaican dollar)	7 years; 1-year moratorium on principal payments
World Bank line	USD 4–6 million	J$30 million (USD 340,000); can be lent in either USD or J$	2.75% to AFI, maximum 5.75% to borrower (USD); 4.5% to AFI, maximum 7.5% to borrower (J$)	10 years; 4-year moratorium on principal payments
DBJ regular funds	Varies	No limit	6.5% to AFI, maximum 9.5% to borrower (J$)	10 years; 4-year moratorium on principal payments
PetroCaribe	Varies	USD 3 million	4.25% to AFI, maximum 7.25% to borrower (J$)	Information not available at publishing
Residential energy investments	Varies	J$2 million (USD 23,000)	6.5% to AFI, maximum 9.5% to borrower (J$)	8 years

Source: See Endnote 12 for this chapter.

PetroCaribe. The costs for these audits can be built into the loan. DBJ also has a grant program for small and medium-sized enterprises that provides up to J$200,000 (over USD 2,000) for energy audits.[13]

While the loan packages in Table 7.1 are mostly at a scale suitable for individuals and small and medium-sized enterprises, DBJ also has the capacity to finance utility-scale power projects from USD 20 million to USD 100 million or more.[14] DBJ assisted the Jamaica Broilers Group (a poultry producer) in financing its ethanol plant, channeling the approximately USD 20 million loan through various commercial banks.[15]

DBJ also has a partial loan guarantee program to address the lack of capacity of commercial banks in Jamaica to accept renewable energy equipment as collateral for loans, which can enable larger-scale project financing.[16] (See Case Study 3.) Through the partial loan guarantee mechanism, DBJ provides a guarantee to the lending bank that it will take responsibility for the debt in the event that the borrower defaults on loan payments. DBJ's loan guarantee program is administered through the J$250 million (approx. USD 3 million) Credit Enhancement Fund and supports up to 80% of the loan amount with a maximum of J$10 million (approx. USD 100,000).[17]

DBJ has additional measures to improve private banks' lending capacity for sustainable energy projects, including through co-financing with local banks and providing assistance in structuring projects to attract international financing.[18] DBJ publishes lists of energy equipment suppliers and energy auditors registered with PCJ that help individuals and businesses find out where to seek energy services.[19]

In addition to DBJ-supported loans, the National Housing Trust (NHT) has programs that support household-level solar PV and solar water heating installations. These loans are offered in addition to regular mortgages for homebuyers. The stringency of current requirements has limited participation in the NHT solar loan programs to-date. In response, the head of Policy and Planning for NHT has recently begun a revision process to make solar PV projects more accessible.[20]

Case Study 3. Partial Loan Guarantees for Chicken House Solar PV Systems

As with many other industries and services in Jamaica, electricity is the largest cost in poultry farm operations. The Jamaica Broilers Group, the largest poultry producer in the Caribbean, has made significant efforts to produce its own energy from renewable resources in order to lower energy costs. In addition to the company's own ethanol production plant, in 2013 Jamaica Broilers began installing solar PV capacity at chicken houses owned by farmers contracted by the company. The project also involved installing energy-efficient LED lighting at the facilities.

The first phase of the solar project aimed to install 15 kW PV systems at about 40 chicken houses— totaling some 600 kW—by the end of March 2013. Each 15 kW system is expected to generate 22 MWh of electricity per year. Phase 1 is aimed at supplying energy for daytime use, and grid access for the PV systems is an important criterion for the addition of more modules in future phases.

The project is estimated to cost USD 10 million over two years. Rather than requiring the chicken farmers to leverage their farms as collateral to purchase the solar equipment, Jamaica Broilers will facilitate obtaining supplies and financing for farmers to lease the equipment, with an expected payback period of five to six years. Each participating farmer applies for the loan, which is financed by DBJ through the National Peoples Cooperative Bank at a 9% interest rate over seven years.

The solar PV project is a pioneer in Jamaica's renewable energy market in that it allows the use of renewable energy equipment—rather than farms—as collateral for loans. Jamaica Broilers has the right on behalf of the banks to repossess and sell the solar equipment if farmers fail to meet loan repayment requirements. The project makes use of DBJ's partial loan guarantee program to enable this process—DBJ provided an 80% loan guarantee in the event of default.

Jamaica Broilers' use of partial loan guarantees and solar PV equipment leasing constitute a creative approach to getting around some of the major barriers to renewable energy financing that persist in the country. The use of these and other emerging financial mechanisms can serve as a model for other individuals and companies seeking to reduce energy costs through substantial sustainable energy projects.

Source: See Endnote 16 for this chapter.

Innovative business models for energy efficiency and renewable energy technologies can further reduce upfront investment costs for consumers. Some companies are already exploring leasing renewable energy equipment, such as solar PV panels, to energy consumers.[21] Through this model, customers reduce their electricity bills and instead pay a monthly fee to the leasing company. For the leasing model to attract debt financing, Jamaican banks need to regard renewable energy equipment as viable collateral. Support mechanisms such as the partial loan guarantee offered by DBJ can help ease this process in the near term. (See Case Study 3.) Alternatively, leases for renewable energy equipment could be paired with car leases, for example, to attach more traditional collateral to the lease agreement.[22]

Government funding for renewable energy assessments is another way to establish a country's renewable energy market in the early stages and to build confidence among private investors and banks. In Jamaica, MSTEM has set out plans to conduct feasibility assessments to expand solar capacity between 2009 and 2014, both in the form of PV and solar thermal for heating and cooling. The solar expansion is being driven by the Petroleum Corporation of Jamaica (PCJ) and the Renewable Energy and Energy Efficiency Department (REEED) with support from the University of the West Indies (UWI) and the University of Technology (UTech), with a combined investment of USD 1.5 million. The solar expansion focuses on small-scale plants of 5 MW or less.[23] In addition, PCJ, REEED, and JPS, in partnership with UWI and UTech, hope to spend USD 58 million promoting 15 MW or larger wind plants between 2009 and 2014.[24]

7.1.2 Capacity Building and Awareness-Raising to Improve Energy Financing

Despite the economic opportunities of sustainable energy projects, until recently Jamaica's energy credit lines faced relatively low participation rates. A September 2011 study found that lack of awareness and public education of the benefits of energy efficiency and renewable energy contributed to the limited uptake of the Energy Fund.[25] In part to address these issues, the Inter-American Development Bank (IDB) and DBJ jointly launched DBJ GreenBiz in June 2012, a roughly USD 800,000 initiative to demonstrate the benefits of energy efficiency measures for small and medium-sized enterprises and to train Certified Energy Auditors and Managers to enable effective use of the Fund.[26] The DBJ GreenBiz initiative aims to increase awareness through public showcases of energy projects, radio and television interviews, advertising, educational workshops and seminars, and an energy fair.[27]

According to DBJ, initial results indicate that the GreenBiz program and other measures have been successful in encouraging uptake of Energy Fund loans. Only between J$300 and J$400 million had been loaned through the fund since its launch in 2008 through early 2012. By late November 2012, however, after the start of the GreenBiz initiative, more than J$600 million in energy loans had been disbursed to small and medium-sized enterprises and residential customers.[28]

Phase 2 of the GreenBiz program will provide partial grants to eight energy efficiency and renewable energy pilot projects with the aim of publishing results of the projects to demonstrate the feasibility of sustainable energy investments in Jamaica.[29] (See Table 7.2.) Initial results from this phase have been promising. Phases 3 and 4 will involve public education and training for energy service companies (ESCOs).

7.1.3 Summary of Domestic Sustainable Energy Financing

The availability of loans for household and small- to medium-scale commercial energy efficiency and renewable energy projects has improved in recent years due to improved capacity in domestic banks, improved awareness of the real risks and opportunities of sustainable energy lending, and increased experience of project developers seeking loans. Nevertheless, investor confidence remains too low and interest rates too high to enable widespread investments in energy efficiency and renewable energy projects across Jamaica.

Efforts such as the DBJ GreenBiz program should be continued in order to continue uptake of available loans and strengthen Jamaica's domestic sustainable energy market. Continued capacity building for both domestic banks and energy developers is needed to reduce real and perceived risks associated with sustainable energy project financing. In the meantime, the major remaining barriers to creating an enabling environment for small- and medium-scale renewable energy investment are related to Jamaica's energy policy framework. (See Chapter 8.)

7.2 Accessing International Sustainable Energy Finance

The funds identified above are geared mostly toward small and medium-sized enterprises and smaller-scale energy investments, and for the most part would not be sufficient for utility-scale renewable energy investments. Additional sources of financing are required for these projects.

International financing has and will continue to play a key role in funding sustainable energy projects in

Table 7.2. DBJ GreenBiz Pilot Projects

Company	Primary Energy-Consuming Activities	GreenBiz Project Components
Triple Seven Farms (poultry farm)	• Lighting • Fans for chicken houses	• Lighting retrofit • Electrical rewiring • Solar hydronic brooding system • Installation of drop roof
Sunrise Club Hotel	• Air conditioning (AC) • Heating equipment • Cooling equipment	• Lighting upgrades • Refit of doors and windows in air-conditioned spaces • Replace AC system with high-efficiency units • Rooftop solar PV • Solar water heating system
Ruthven Medical Centre	Not provided	• AC unit retrofits • Power factor correction • Electrical relocation
Pioneer Meat Products (meat processing, packaging, and distribution plant)	• Refrigeration • AC • Air compressor • Diesel smoke houses • Boiler	• Timers (to enable time-of-use option for electricity usage) • Power factor correction • Boiler maintenance • AC unit retrofits
NASA Farms Limited (dairy farm and drinks manufacturer)	Not provided	To be determined
Footprints on the Sands (hotel)	• AC	To be determined
CANCO Limited (canned food manufacturer)	Not provided	• Installation of electricity meters • Lighting retrofits • AC unit retrofits • Steam recovery system installation • Insulation of steam retorts

Source: See Endnote 29 for this chapter.

Jamaica. Examining past and current internationally financed programs demonstrates the importance of this funding source, as well as potential future opportunities and projects that would be well suited to receiving additional finance.

7.2.1 Harnessing Private International Finance

Jamaica is a heavily indebted country, which could limit its ability to obtain the large amounts of international financing necessary for a significant shift to renewable energy. Jamaica's national debt burden poses a barrier to accessing international financing for public programs, such as a feed-in tariff. It also creates an indirect risk for lending in the private sector, causing international institutions to charge high interest rates for energy loans in the country.[30] The Jamaican government's new loan agreement with the IMF through 2016–17 should provide increased investment stability in the near term.

Although most of Jamaica's own banks are still building capacity to lend for large-scale renewable energy projects, international banks can provide larger loans. Jamaica's overall risky investment environment, however, currently discourages involvement from international banks. Jamaica scores low on international rankings of competitiveness (97th out of 144 countries) and ease of doing business (90th out of 185 countries), due in large part to lack of available credit as well as to bureaucratic barriers relating to registering property, paying taxes, and enforcing contracts.[31]

Nevertheless, there are steps that the Jamaican government and banks can take to facilitate international sustainable energy loans within the country. Nicaragua serves as a regional example of how to overcome investment barriers to sustainable energy, despite ranking among the lowest-performing countries in global competitiveness and ease of doing business. In 2012, the IDB's *Climatescope* report ranked Nicaragua second out of 26 Latin American and Caribbean countries for its ability to attract clean energy financing, due in large part to government incentives and investment in the sector.[32] Because of Jamaica's renewable energy goals in its National Energy Policy, as well as the country's recent wind capacity additions, *Climatescope* ranked Jamaica 16th out of 26 countries (and second in the Caribbean) for its ability to attract clean energy financing.[33]

Ultimately, significant increases in sustainable energy lending will require a more stable investment environment for energy efficiency and renewable energy projects. This will require streamlining general bureaucratic barriers, as well as measures targeted at the energy sector.

7.2.2 Traditional Development Assistance for Sustainable Energy Projects

Increasingly, multilateral development banks and bilateral aid from donor countries are focusing grants and loans on energy efficiency and renewable energy projects, rather than on conventional fossil fuel infrastructure such as coal power plants. Countries like Jamaica that have emphasized the importance of sustainable energy in national development strategies have a better chance at accessing aid for these purposes.

Jamaica has harnessed financing from development agencies in the past to support specific renewable energy capacity investments (for example, Wigton Windfarm) and energy efficiency projects (such as energy audits), as well as capacity building programs within the Jamaican government and finance sectors to promote institutional strengthening and policies in support of sustainable energy. One promising area where international assistance can help scale up private investment in energy efficiency and renewable energy is to provide loan guarantees for these projects to ensure that all loan payment obligations will be met if the project developer defaults.

Several governments, international organizations, and non-governmental organizations have directed monetary and technical assistance to Jamaica to support energy sector development, including the World Bank, IMF, IDB, United Nations Development Programme (UNDP), U.S. Agency for International Development, U.S. Trade and Development Agency, Organization of American States, and Caribbean Development Bank (CDB).[34] The CDB has loaned money to Jamaica for various development improvements, and in a 2011 address to the CDB, Audley Shaw, Jamaica's Minister of Finance and Public Service, asked for further assistance in greening the country's industries.[35]

7.2.3 The Future of Climate Finance: From the Clean Development Mechanism to Nationally Appropriate Mitigation Actions

In the United Nations Framework Convention on Climate Change (UNFCCC) negotiations, developed countries have pledged climate funds rising to USD 100 billion per year by 2020.[36] Although the exact nature and mechanisms for this financing are yet to be determined, these funds will most likely be disbursed through multiple channels and come from public, private, bilateral, and multilateral sources. In addition, alternative sources of finance will be channeled through the Green Climate Fund (see discussion below).

In general, climate financing for sustainable energy projects aims to support the incremental costs of upfront capital compared to business-as-usual investments in fossil fuel generation. The energy pathway socioeconomic assessment for Jamaica presented in Chapter 6 of this Roadmap demonstrates this need for additional upfront investment for renewable energy development compared to BAU.

MSTEM has identified climate finance sources under the Global Environment Facility (GEF) and Clean Development Mechanism (CDM) as part of the strategy to generate capital for low-carbon investment.[37] The CDM, established by the Kyoto Protocol through the UNFCCC process, is an institutional device that allows developing countries to reduce the costs of their transition to sustainable sources of energy, while giving developed countries more flexibility in achieving their binding emissions reduction objectives.

Latin American and Caribbean countries made up only 14% of past CDM projects worldwide, compared to 46% in China and 21% in India.[38] Wigton Windfarm is Jamaica's only CDM-certified project.[39] (See Case Study 4.) As of mid-2013, CDM prices had plummeted to less than 50 U.S. cents per ton of carbon due to an oversupply of credits, causing a steep drop in new CDM project financing: new carbon credit contracts fell 91% between April 2012 and April 2013.[40] In July 2013 the UNFCCC and St. George

Case Study 4. Financing Wigton Windfarm

With an installed capacity of 38.7 MW, Wigton Windfarm is the largest of Jamaica's two commercial-scale wind farms. Phase I of the Wigton facility was commissioned in 2004 with an initial capacity of 20.7 MW. The project cost USD 26 million, consisting of USD 7 million from a grant from the Dutch government, and loans of USD 16 million from the National Commercial Bank (NCB) and USD 3 million from PCJ. Following an increase in the NCB loan interest rate to more than 11%, the PetroCaribe Development Fund took over this loan initially at a 4% interest rate, rising to 6% in July 2013.

Under the 20-year agreement, Wigton sold electricity to JPS at a rate of 5.6 U.S. cents per kWh for the first five years, and 5.05 U.S. cents per kWh thereafter. These rates were too low for the wind farm to be profitable, and Wigton only began turning a profit when the tariff was revised to reflect the updated avoided cost level. A key factor in enabling Wigton's profitability was that rather than steady payments at the avoided cost level over time, the tariff that Wigton receives is higher in the first few years to allow the company to recover high upfront capital costs, and then lower in later years, averaging out to the avoided cost.

Phase II added 18 MW of capacity and began exporting electricity to the grid in December 2010, at a cost of USD 49 million financed by Jamaica's PetroCaribe Fund.

Wigton Phase I financing was supplemented by sales of carbon credits to the Netherlands at a price of EUR 5.50 per ton of CO_2. Although Phase II is a certified Clean Development Mechanism project, Wigton has refrained from going to market because carbon credit prices are too low to make it worthwhile.

According to Wigton officials, the major barrier to further capacity expansion was the low avoided cost-based price for wind generation by independent power producers, at less than 11 U.S. cents per kWh; officials stated that an offtake price of 13–14 U.S. cents per kWh (including financing costs) would be necessary to make additional capacity viable at Wigton. In November 2012, Jamaica's electricity regulator suspended new renewable energy capacity through the avoided cost system in favor of a competitive tendering process. (See Chapter 8.) This shift in policy is likely behind Wigton's recent announcement of plans for an additional 24 MW wind expansion by 2015.

Source: See Endnote 39 for this chapter.

University in Grenada launched a joint initiative to build capacity in the Caribbean region to access CDM financing; Jamaica is one of several target countries under this initiative.[41] The future of CDM financing for Jamaica is uncertain, however, as some countries have argued in climate negotiations that CDM funds should be reserved for least-developed countries, while upper-middle income countries such as Jamaica will have access to climate funds through new programs, including Nationally Appropriate Mitigation Actions (NAMAs).

NAMAs are one of the main pillars of future climate finance. Currently, NAMA guidelines remain loosely defined; however, there is strong interest on the part of several multilateral and bilateral climate finance sources for recipient countries to design NAMAs that will be ready to receive funding once the bureaucratic details are finalized. One of the benefits of the current loose structure of NAMA programs is that they can include a broad range of sustainable energy activities, including support for specific renewable energy capacity additions, funding to support renewable incentive mechanisms such as feed-in tariffs and energy efficiency programs, and capacity building and institutional strengthening for sustainable energy governance. In addition to climate mitigation, NAMAs are required to demonstrate co-benefits, such as job creation opportunities and health improvements from reduced local air pollution.

The German and U.K. governments have already set up a joint NAMA facility designed to support developing countries that, in the short term, want to implement transformational country-led initiatives within the existing global mitigation architecture. The UNFCCC established a registry to match NAMAs of developing countries with financial, technological, and capacity-building support from donor countries. Bilateral climate finance from individual donor countries should be explored, as well as funding from multilateral agencies. The GEF, administered through the World Bank, has been a major source of international climate finance since it was established in 1991.

More recently, in 2008, the World Bank along with several other regional development banks established the Climate Investment Funds (CIFs), which include programs dedicated to renewable energy and energy efficiency. In parallel through the UNFCCC process, countries agreed to establish a new Green Climate Fund (GCF) to function as the convention's financial mechanism. Its goal is to provide substantive support to international efforts to combat climate change, and it is expected to channel a significant portion of climate finance in the future.

Jamaica has active initiatives to support sustainable energy through concrete projects, policies, and countrywide planning, providing the opportunity to secure climate financing in support of these efforts. Specific policies and programs that could benefit from climate finance opportunities, including NAMAs, are examined in Chapter 8.

7.3 Financial Summary Recommendations

Capacity within Jamaican banks to provide sustainable energy financing has increased greatly in very recent years. Additional education and outreach is needed to inform energy developers about recent positive developments in available financing, including the lowered interest rates for energy efficiency and renewable energy projects. In addition, the new IMF deal will have a significant impact on Jamaica's capacity to promote a sustainable energy transition. Due to the large contribution of petroleum import reliance to Jamaica's external debt, the IMF has once again acknowledged the important role of favorable efficiency and renewable energy policies in strengthening Jamaica's financial situation.

International finance has an important role to play in supporting sustainable energy development in Jamaica, especially for large-scale projects. Because Jamaica is currently viewed as a risky country for investment due to its debt situation and high interest rates, reducing bureaucratic hurdles and instituting risk-management measures such as loan guarantees for sustainable energy projects will be essential for attracting international finance in this sector. Finally, international assistance including climate finance can help bolster Jamaica's sustainable energy markets through individual projects as well as the development and implementation of sustainable energy support policies.

8 | Policies to Harness Sustainable Energy Opportunities in Jamaica

Key Findings

- The largest barriers to achieving a sustainable energy transition in Jamaica can be overcome through smart policies.
- The current uncertainty over natural gas and coal options for diversifying Jamaica's electricity mix highlights the importance of scaling up renewable generation to meet energy needs in both the near and long terms.
- Jamaica's National Energy Policy sets important targets for energy efficiency and renewable energy; these should be strengthened and embraced across all agencies.
- The role of the Jamaica Energy Council should be strengthened, and participation should be expanded to all relevant Ministries in order to mainstream energy priorities throughout the government.
- The Office of Utilities Regulation (OUR) mandate to ensure affordable electricity prices from diverse energy sources must be strongly enforced.
- Transferring electricity planning and procurement processes from OUR to the Ministry of Science, Technology, Energy & Mining (MSTEM) would facilitate greater renewable energy development.
- Streamlining currently lengthy and bureaucratic permitting procedures would eliminate a major source of renewable energy investment risk.
- Jamaica has in place several new policies to promote renewable energy, including net billing, electricity wheeling, and a request for proposals for renewable capacity; these should be implemented to their fullest potential.
- Measures that have proven successful in other countries—including net metering programs and renewable feed-in tariffs—provide additional options for future policies in Jamaica.

Jamaica is at an energy crossroads: the country has shelved plans to transition to natural gas for the time being, and has not yet developed a comprehensive program for coal-based energy. The need for an immediate path forward presents a unique opportunity to refocus Jamaica's energy diversification efforts on the opportunities of energy efficiency and renewable energy presented throughout this Roadmap. Over the past few years, Jamaica has instituted important policies to promote renewable energy. However, despite Jamaica's extensive opportunities for energy efficiency, strong renewable energy resources, and the socioeconomic benefits of transitioning to sustainable energy, the necessary investments are not being made.

Our analysis suggests that policy frameworks in countries that have succeeded in developing a favorable investment climate for sustainable energy solutions share three important elements: (1) a long-term national vision with sustainable energy at the core, (2) an effective and streamlined administrative and regulatory structure for promoting sustainable energy, and (3) concrete support policies and measures. In each of these areas, it is essential to determine the major barriers to sustainable energy deployment and to identify policy enablers to overcome them. This chapter presents an overview of Jamaica's current situation in each of these three areas, and provides targeted recommendations for strengthening the country's energy policy and regulatory framework.

8.1 Establishing a Long-Term Sustainable Energy Vision

In 2009, the Ministry of Science, Technology, Energy & Mining established a National Energy Policy through 2030, which is Jamaica's overarching document for energy planning. The Policy includes a target for a 20% renewable share of primary energy consumption by 2030.[1] In 2012, MSTEM Minister Phillip Paulwell announced a more ambitious target of 30% electricity from renewable energy sources by 2030, although this target has not yet been incorporated into official policy.[2]

The National Energy Policy outlines energy efficiency goals, including a target to reduce the energy intensity of the Jamaican economy by more than 70% by 2030. The Policy also includes a target to reduce technical losses from electricity transmission and distribution from 10% to 8.5% of net generation by 2014, and to reduce non-technical losses by 2.6%.[3]

The National Energy Policy is an important document that goes a long way to mainstreaming and solidifying sustainable energy goals in the national agenda; however, based on this Roadmap's assessments of Jamaica's strong renewable resources, opportunities for grid strengthening, and socioeconomic benefits of renewable energy development, the country should increase its national renewable energy targets significantly beyond the 30% by 2030 goal of the current administration. A renewable energy target of more than 90% by 2030 is not only technically possible and environmentally beneficial, but also economically feasible.

Furthermore, Jamaica needs to develop sector-specific renewable energy targets in support of its overall renewable energy consumption targets for electricity, transportation, and other sectors. Although government officials speak of the 20% and 30% renewable energy targets with regard to the electricity sector in particular, in official documentation the targets are set for the renewable share of all primary energy consumption.

The Jamaican government should set an electricity-specific target of at least 30% of total generation by 2030, and preferably higher. In fact, given that the electricity sector is just one of several major energy-consuming sectors, and that the opportunities for high renewable energy penetration are much more limited in other sectors such as transportation and alumina production, a 30% renewable share of primary energy would implicitly require a renewable electricity target of over 80%. Jamaica should also clarify its schedule for retiring its aging and inefficient facilities.

Despite the National Energy Policy, the importance placed on energy efficiency and renewable energy continues to vary among government agencies. Even within MSTEM, energy diversification plans are still centered around fossil fuels—either LNG or coal. The Office of Utilities Regulation's (OUR) 2010 Generation Expansion Plan, which details electricity planning and procurement for Jamaica through

2029, mentions the 20% renewable target but highlights the variability and integration challenges as a barrier to significantly reducing the role of fossil fuels in the energy mix.

The Planning Institute of Jamaica's (PIOJ) Vision 2030 Plan, which aims to lift the island to developed-country status by 2030, supports the deployment of renewables but argues that fossil fuels will dominate until at least 2030, again due to perceived technical and variability challenges associated with renewable energy generation. Without differentiating between different renewable energy technologies, Vision 2030 states broadly that "these alternative solutions are not yet ready for adoption for large-scale commercial use."[4] The document does, however, call for taking climate change risks into account in Jamaica's development planning.[5]

Jamaica's June 2011 Second Communication to the UNFCCC includes an emissions abatement plan that highlights the National Energy Policy.[6] However, the three emission scenarios conducted in the document do not clearly reflect renewable energy targets, and in fact the business-as-usual case results in the lowest projected emissions.[7]

Despite the coordinating aim of Jamaica's National Energy Policy, these positions in MSTEM, OUR, PIOJ, and UNFCCC communications reveal a continued prioritization of fossil fuel energy sources above sustainable energy options throughout the Jamaican government. Unified messaging regarding the importance of putting energy efficiency and renewable energy at the heart of Jamaica's development is needed to send a strong signal to policymakers and investors about the importance of meeting these targets. Ideally, Jamaica should pass much stronger, sector-specific renewable energy and energy efficiency targets. To ensure that policymakers are held accountable to energy plans, these targets should be widely communicated to the public. Monitoring and verification processes should also be put in place to track progress toward meeting targets.

Finally, integrating Jamaica's national targets into a regional energy plan can lend them greater international weight and impact, and can hold the government accountable to its neighbors in meeting climate-related goals. Worldwatch has worked with the Caribbean Community (CARICOM) Secretariat to develop regional targets for energy efficiency, renewable energy, and greenhouse gas emissions through 2027. In March 2013, these targets—including a regional goal of 47% renewable electricity by 2027—were provisionally adopted by delegates from CARICOM's 15 member countries. MSTEM Minister Phillip Paulwell called the decision "historic" and celebrated the regional momentum for addressing energy problems in the Caribbean.[8]

8.2 Administrative Structure and Governance

Overarching national energy plans and targets are just one part of the planning and policy framework necessary for a sustainable energy transition, and alone are not enough to ensure that these goals will be met. Jamaica's mixed past experience with setting goals for renewable energy capacity highlights the importance of implementing strong support measures to back these policies.

Institutional and regulatory barriers also stand in the way of achieving a significant share of renewable energy in Jamaica. In particular, OUR, the country's electricity regulator, has fallen far short of its mandate to increase renewable energy capacity and maintain affordable electricity prices in Jamaica.

MSTEM currently does not have the oversight authority to hold OUR accountable to effectively regulating JPS.

8.2.1 Mainstreaming Sustainable Energy Policy and Regulation

Because energy issues affect such a broad range of sectors, a multitude of government agencies with overlapping—and sometimes opposing—mandates and priorities are involved in various aspects of energy planning and regulation in Jamaica. Greater ministerial cohesion would help sustainable energy policies gain traction in the Jamaican Cabinet and Parliament. In one example, approval from the Ministry of Finance was needed for tax exemptions for energy efficient and renewable energy equipment. In a less successful case, MSTEM was unable to convince the Jamaican Cabinet to pursue renewable feed-in tariffs.

The Jamaica Energy Council already serves as an energy decision-making forum that brings together diverse government and non-governmental stakeholders. MSTEM established the Council in early 2012 as a bipartisan, multi-stakeholder platform with the goal of reducing energy costs for households and businesses and increasing competition in the electricity sector. The Council is co-chaired by Minister Phillip Paulwell and the opposition party's Spokesman on Energy, Gregory Mair. Other members include representatives from the American Chamber of Commerce of Jamaica, the Jamaica Chamber of Commerce, the Private Sector Organisation of Jamaica, the Jamaica Manufacturers' Association, the Small Business Association of Jamaica, and renewable energy experts.[9]

The Jamaica Energy Council has had some early achievements to date. It has been credited with facilitating approval of energy efficiency tax exemptions by the Ministry of Finance, a potentially difficult task given the country's debt situation and ongoing negotiations with the IMF at that time. The Council has also worked to streamline procedures for Jamaica's new net billing program that allows small-scale distributed renewable generators to feed electricity into the grid. In addition, the Council has established a subcommittee on public engagement.[10] Nevertheless, critics of the Jamaica Energy Council point to its inability to solve some of Jamaica's larger-scale energy problems, including reducing electricity costs, moving forward with LNG plans, and implementing more-ambitious renewable incentive policies.[11]

This initiative should be strengthened and expanded to provide the needed platform for policy mainstreaming and coordination by including representatives from the Ministry of Finance; the Ministry of Water, Land, Environment & Climate Change; the Bureau of Standards of Jamaica; the Planning Institute of Jamaica; and other relevant government agencies. The Petroleum Corporation of Jamaica should also be included in the process; the state-owned energy company recently took an important step in facilitating renewable energy development by publicizing all of its renewable resource technical and feasibility assessments. PCJ should be involved in multi-stakeholder processes to facilitate energy planning and information sharing with developers and investors.

8.2.2 Reforming Electricity Sector Regulation

Jamaica's electricity sector is regulated by the Office of Utilities Regulation (OUR), established as an independent regulatory agency in 1995. OUR is also responsible for the procurement process for new generation capacity, as well as the preparation of the Least Cost Expansion Plan for Jamaica's electricity sector.[12]

OUR has a troubled track record of accountability to its mandate to promote energy diversification from domestic resources and to ensure affordable electricity prices, including setting electricity purchase tariffs for independent power producers (IPPs) at levels that favor JPS. Under OUR's regulation over the past few years, electricity prices for Jamaican households have skyrocketed to near 40 U.S. cents per kWh, and grid losses have increased. (See Chapter 1.) Some stakeholders within Jamaica cite regulatory capture as a significant barrier to OUR's regulatory independence, with most OUR officials having a history of employment with JPS.

Renewable generation capacity has also stagnated under OUR, with the notable exception of Wigton Windfarm. Until November 2012, OUR procured new renewable capacity under 25 MW with pricing for IPPs based on the avoided cost of future anticipated electricity generation, plus a 15% cost premium. In the most recent regulation in effect from 2010 to 2012, this resulted in a maximum possible payment of 10.73 U.S. cents per kWh for renewable power generation, too low to incentivize new projects. OUR's current request for proposals (RFP) for renewable capacity, which signals a transition away from the avoided-cost model and has the potential to significantly improve renewable energy investment in Jamaica, is assessed in more detail later in this chapter.

The extension of OUR's authority over energy planning, Least Cost Expansion Plans, and capacity procurement far exceed the normal oversight powers of an electricity regulator, and interfere with its independence in regulatory decision making.[13] Furthermore, despite OUR promises to abide by MSTEM directives, the regulator's commitment to meeting government renewable energy targets and mandating the necessary grid improvements to accommodate these power sources remains questionable. OUR has not audited JPS in several years, although the Jamaican government is now calling for this to be done.[14]

A new electricity policy and accompanying legislation are necessary to strengthen OUR's directives and MSTEM authority over the electricity sector. Current efforts by MSTEM (including the Modernize Electricity Act, examined in Section 8.3) to take on electricity planning and procurement and strengthen oversight of OUR's regulatory authority should be supported to ensure that Jamaica meets its renewable energy targets, and that JPS sets fair electricity prices that accurately reflect generation costs and enable access to affordable energy for Jamaican consumers and businesses.

OUR also should be required to enforce the quality of energy services provided by JPS, including through sanctions.[15] The quality of energy services should cover the reliability of electricity supply, including the length and frequency of outages. The electricity regulator should also require grid improvements to reduce technical losses and strengthen enforcement of measures to reduce electricity theft.

8.2.3 Streamlining Renewable Capacity Permitting: A Single Administrative Window

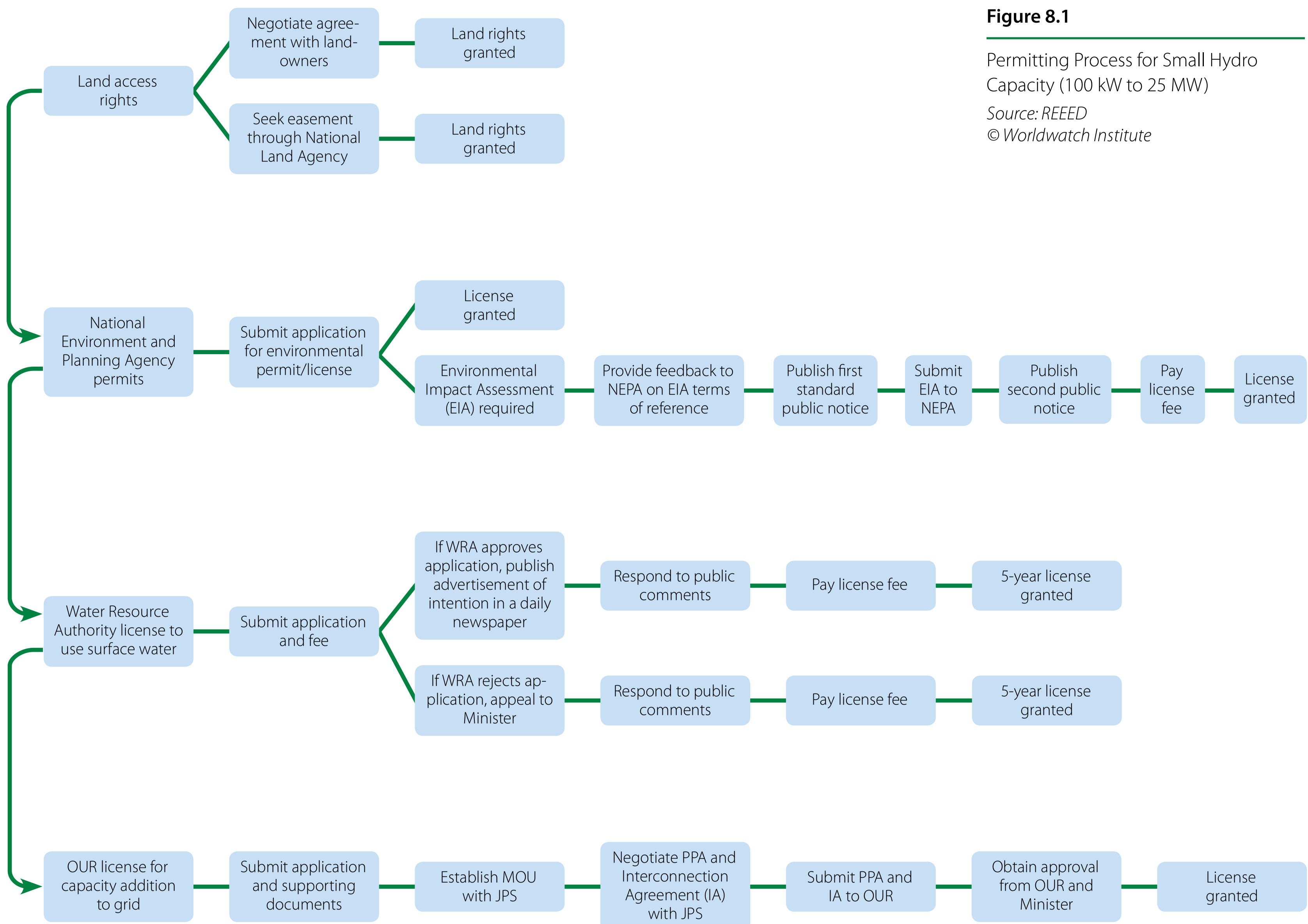
In the National Energy Policy, MSTEM recognizes time-consuming administrative procedures for project development as a major barrier to renewable energy project development.[16] Examining the permitting requirements for small hydropower capacity additions illustrates the hurdles facing renewable energy project developers.[17] (See Figure 8.1.) As of July 2013, MSTEM and PCJ were working with the U.S. Federal Energy Regulatory Commission to find solutions across the 10 relevant government agencies to reduce hydro permitting processes to less than one year from application to final permit issuance.[18]

Although permitting processes for each type of renewable energy facility may vary somewhat (e.g., solar and wind installations might not require water use licenses, and residential installations will not often involve land rights negotiations), this framework provides an idea of steps involved. Effective

Figure 8.1

Permitting Process for Small Hydro Capacity (100 kW to 25 MW)

Source: REEED
© Worldwatch Institute



permitting is essential to ensure that the negative environmental and social impacts of energy projects are limited; however, long and bureaucratic permitting processes can result in significant risk and expense, discouraging developers and investors from undertaking renewable projects.

Grid connection is often the longest, most uncertain, and costliest part of the permitting process. In addition to permit requirements displayed in Figure 8.1, Jamaica's Government Electrical Inspectorate (GEI)—the government agency responsible for certifying electrical installations—established requirements for certification of grid-connected renewable energy systems, especially solar PV. Key elements include: 1) a written request for system inspection and design approval, 2) an OUR license, and 3) a diagram of the complete system.[19] Worldwatch recommends that MSTEM and OUR guarantee grid access for renewable energy installations, which should eliminate most of the uncertainty and delay associated with this step.

One way that the government can reduce land acquisition conflicts and delays associated with renewable energy projects is to open up public lands for renewable energy development. In particular, the Jamaican government can establish a bidding process for companies to submit applications to develop specific sites on public land known to have strong solar or wind potential.

Accountability measures for the various government agencies involved in renewable energy permitting should be implemented to ensure timely and efficient procedures. The National Land Agency, National Environment and Planning Agency, Water Resource Authority, OUR, and any other relevant actors should be required to respond to permit applications within set time frames.

In addition to stronger institutions and regulatory mandates, Jamaica needs more-consistent and straightforward procedures for investing in, building, and operating renewable energy capacity. The Development Bank of Jamaica has developed an Environmental Management Framework (EMF) to guide financing institutions and energy developers through the permitting and legal framework for renewable energy projects.[20] DBJ also provides developers and investors with the Environmental Policy and Management System (EPMS), a guide of policies and procedures to help projects meet financial quality and environmental standards.[21]

The EMF and EPMS programs are a strong start for addressing bureaucratic barriers and delays by providing energy developers with a single resource for capacity building and guidance on project compliance. These programs should be further strengthened in order to provide guidance for large- and utility-scale projects in addition to small-scale investments.

International best practice demonstrates a single administrative window where developers can obtain the necessary permits, concessions, and eligible incentives to greatly simplify renewable energy development. One option for Jamaica to streamline bureaucratic procedures in this manner is to institutionalize EMF and EPMS activities under MSTEM.

As examined in Chapter 7, the lack of economically sound contractual arrangements between JPS and IPPs also hinders investments in viable renewable potential.[22] MSTEM, OUR, and JPS should work together to develop a standard contract and power purchase agreement (PPA) for renewable installations to increase investor confidence in the stability of sustainable energy investments in Jamaica.

8.2.4 Establishing a Greenhouse Gas Monitoring Program

To support a stronger demonstrated commitment to addressing climate change, Jamaica needs to institute a robust program for greenhouse gas monitoring to ensure that its sustainable energy measures achieve the anticipated environmental benefits. Effective greenhouse gas monitoring programs require strong monitoring, reporting, and verification mechanisms in order to ensure thorough and accurate data availability. Such programs can provide key information about priority sectors to target for future emissions reductions. A reliable monitoring program can also assist Jamaica in harnessing international climate funds to finance its clean energy projects, including through Nationally Appropriate Mitigation Actions, as discussed in Chapter 7.

Over the last few years, the Jamaican government has been pursuing a carbon-impact monitoring tool that will enable it to track its energy use and related greenhouse gas emissions. This important initiative, led by MSTEM in conjunction with Echos Consulting, will result in a web-based tool that monitors energy use in the various government buildings in Jamaica. This is an important project that will help increase energy efficiency awareness, reduce energy use, lower fossil fuel use for electricity generation, and reduce Jamaica's greenhouse gas emissions. It can promote more-efficient use of government office space, replacement of outdated and inefficient equipment, and staff training around issues of energy awareness.

This initiative is in keeping with the country's long-term energy vision established by MSTEM. As one of Jamaica's largest electricity consumers, the government can lead the way to emissions reduction through active tracking of its energy use and implementation of efficiency measures. The carbon-impact monitoring tool will play an important role in realizing the country's stated objectives and should continue to be supported and developed across all government ministries and departments.

8.3 Recommendations for Strengthening Existing Policies

Jamaica's legal and policy framework for the energy sector has several provisions to promote energy efficiency and renewable energy in the electricity sector. The breadth and effectiveness of these policies are examined below.

8.3.1 Energy Efficiency Measures

Energy Efficiency Programs

The Jamaican government and JPS have several ongoing energy efficiency initiatives to reduce residential, commercial, and industrial energy consumption.[23] (See Table 8.1.) Current programs that provide energy audits, public education about the benefits of energy conservation, and strong government efficiency goals and procurement of energy efficient technologies have all been proven as effective measures for reducing energy consumption. In particular, free home energy audits would encourage Jamaican households to implement energy-saving measures to save on utility bills.

Energy Efficiency Standards

The Bureau of Standards of Jamaica (BSJ) oversees the country's mandatory national energy labeling standard for refrigerators and freezers. The labeling program requires appliance retailers and importers

Table 8.1. Current Energy Efficiency Programs

Program	Established	Key Aspects
Energy Efficiency and Conservation Programme (MSTEM)	2012, total of 20 years, with 4-year Phase 1	• USD17 million for hardware (solar lighting, CFLs, LEDs, sealing and insulation, solar water heating, high-efficiency AC) • USD 1.7 million for institutional strengthening • USD 1 million for demand-side management and energy efficiency best practice education
JPS SmartEnergy program	2012	• Office energy efficiency program • Energy audit certification seminar • Stakeholder education meetings • Business customer energy management training program
Public sector energy conservation	2012–2015	• Goal of 30% energy cost saving in the public sector through energy conservation • Project implementation funds will prioritize local companies; local bidders will win contracts if they are within 15% of foreign bids
JPS Marketing and Energy Services Department	Began as a commercial energy audit program of JPS DSM project, 1996–1998	• Provides energy audits to commercial and industrial consumers at-cost

Source: See Endnote 23 for this chapter.

to have BSJ test and label each model of refrigerator and freezer for annual energy consumption. Baseline efficiency standards and high-efficiency performance incentives for additional energy-consuming appliances and equipment would reduce residential energy consumption. These programs should be continued and supplemented with additional measures. The list of common household electrical appliances provided in Chapter 2 provides an overview of what new standards would have the greatest impact.

Efficiency standards for large commercial and industrial operations also have the potential to significantly reduce economy-wide energy consumption. For example, there are currently no efficiency standards for bauxite mining and refining, despite the sector's disproportionate energy consumption. (See Chapter 2.) BSJ and MSTEM should collaborate to set minimum efficiency baselines for bauxite/alumina equipment and provide incremental tax incentives for high efficiencies exceeding the standards.

Tax Exemptions

Taxes and import duties on energy efficiency and renewable energy technology imports can disincentivize investments by increasing technology costs, in some cases by more than 20%. Because high capital costs are already one of the largest barriers to renewable energy development, this additional cost can make otherwise viable projects unprofitable.[24]

General consumption tax (GCT) exemptions in Jamaica were implemented through the GCT Act in early 2012, and are applied broadly, especially across energy efficiency and solar technologies. LED light bulbs are still subject to a 21.5% GCT tax, but a six-month LED GCT waiver went into effect on December 13, 2012. It is expected that the LED exemption will be extended and codified in the GCT Act, pending Cabinet approval.[25] Import duty reductions and exemptions should also be extended to high-efficiency equipment.[26]

In addition, Jamaica's GCT is currently applied to electricity consumption, raising the country's already high electricity prices for consumers. MSTEM has announced its intention to remove this tax to reduce consumer rates, although this has not yet occurred.[27]

Several renewable technologies are still subject to import duties in Jamaica. Import duty exemptions require the approval of CARICOM, an organization that promotes economic integration and cooperation in the Caribbean region. As of January 2013, the Jamaican Cabinet is seeking CARICOM clearance for import tariff exemption on several energy efficiency and renewable energy technologies.[28] (For a full list of GCT tax exemptions and Cabinet recommendations for import duty exemptions, see Appendix XIII.)

Jamaica's investment and export promotion agency, JAMPRO, implemented measures to encourage renewable energy investment in addition to GCT and import duty exemptions, including tax credits for renewable energy projects and accelerated depreciation benefits that allow full write-off of new equipment costs.[29]

National Building Act of 2011

Recent legislation in Jamaica will facilitate energy efficiency measures in the building sector. The National Building Act of 2011 establishes a National Building Code and promotes energy efficient buildings among its main objectives. The Act also established the Standards Authority, which works to incorporate applicable international standards into Jamaica's National Building Code and serves as the certifying authority for building standard compliance.[30]

The National Building Code is currently in draft form, and will include the first mandatory building efficiency measures in Jamaica. The National Building Code will adapt the 11 building code sections of the International Code Council (I-Codes), including one on energy conservation, which have been adopted across the United States and several other countries and regions. The I-Codes are accepted internationally and updated every three years.

The Standards Authority will develop accompanying documents for each of the 11 I-Codes to tailor them to the Jamaican context and provide alternative methods for compliance that take into account the national construction industry, local factors such as weather patterns, and local technologies and good building practices.[31] Code compliance will occur at three stages: design review before construction begins, issuance of a building permit upon design approval, and monitoring and inspections during construction. Compliance assessments will be administered by local authorities and building inspectors, and will be coordinated by BSJ.[32]

Training of construction staff and compliance officials is key to ensuring effective implementation of the National Building Code. Training is being conducted through the University of Technology, Jamaica (UTech), Human Empowerment and Resource Training (HEART), and ICC training and certification.[33]

In addition to energy conservation standards, the Electricity Division of the National Building Code released standards for installation of solar PV systems on buildings in May 2012.[34] The Code requires BSJ approval for meters, power inverters, solar panels, wind turbines, fuses, and circuit breakers associated with building renewable energy systems.[35] These provisions will ensure that distributed renewable generation installations will not disrupt electricity supply.

Measures to Reduce Technical Grid Losses and Electricity Theft

As examined in Chapters 1 and 4 of this Roadmap, Jamaica currently experiences high electricity losses on the JPS grid, with total losses of 22.3% in 2011. JPS is required to absorb all financial losses that result from grid electricity losses above 17.5%. In June 2012, OUR denied JPS's request to raise the level of grid losses to 18.5%.[36]

JPS has announced plans to reduce technical losses from 10% to 8.5% by 2014 through USD 2.1 million in investment to replace aging conductors, USD 2 million on VAR management for voltage control equipment, and USD 3.1 million on strengthening the primary distribution network.[37]

JPS estimates that illegal connections cost the utility USD 20 million per year. JPS is aiming to reduce these losses by regularizing 10,000 illegal customers per year through legitimate connections, and by auditing about 20% of its customers per year. Automated metering reduces theft by regularizing unregistered customers and preventing meter tampering by JPS customers. Audits to investigate electricity theft can also reduce non-technical losses. As of the end of 2011, JPS had installed 4,000 smart meters for its largest customers, accounting for 30–40% of the company's electricity sales. JPS also installed 10,000 automated meters for residential consumers in communities with high electricity theft and strengthened its auditing efforts with 100,000 audits in 2011.[38]

The successful JPS Residential Automated Metering Infrastructure (RAMI) pilot project in three high-loss parishes reduced losses there from 85% to 5% in 2010 and increased the volume of electricity sales by three times.[39] OUR reports that some of the initial positive results of the RAMI program have since declined, despite additional low-hanging fruit for targeting loss reduction efforts. This program should incorporate lessons learned from early-phase successes and failures, and should be expanded throughout the country along with additional anti-theft measures, including eliminating low-tension wires that facilitate illegal connections.

Despite these programs, JPS still has had problems getting new customers to honor their commitments, and theft has increased in response to increased electricity tariffs from the rising price of oil imports. Successful measures to reduce electricity theft in other countries can provide best practices for JPS and energy regulators. In Venezuela, the utility hired social workers to mediate its theft-reduction efforts in low-income communities. This resulted in reduced electricity theft by providing these communities with more reliable electricity services at affordable rates.

8.3.2 Renewable Energy Measures

Electric Lighting Act of 1890: All-Island Electricity License

JPS has exclusive rights over electricity transmission and distribution in Jamaica through 2027, under the Electric Lighting Act of 1890.[40] Although having a single grid operator can be an efficient way to run a grid system, the long-term exclusive license has come under fire due to concerns about subpar quality of service and high electricity prices under JPS. Because JPS also controls 75% of Jamaica's electricity generating capacity, the JPS grid monopoly is seen as a contributing factor to limited competition from independent power producers. These concerns are aggravated by the current lack of effective regulation by OUR of the JPS transmission and distribution monopoly.

A landmark July 2012 Jamaican Supreme Court decision by Justice Bryan Sykes invalidated the JPS exclusive license, saying that the energy minister at the time improperly granted the license in 2001 without considering other applications.[41] In October 2012, Minister Phillip Paulwell announced that MSTEM would break up the JPS monopoly. He specified that JPS would still be the main entity responsible for the transmission and distribution network, but that disbanding the monopoly would allow for grid interconnection, which would facilitate distributed renewable energy on the grid and encourage competition in the electricity generation sector.[42] Nevertheless, JPS is currently challenging the decision, and the Jamaican government has signed on to its appeal.[43]

Net Billing

Starting in May 2012, a renegotiation of the JPS electricity license resulted in a net billing provision that allows JPS customers engaged in small-scale renewable energy generation to feed excess electricity that they do not consume to the grid. Net billing-eligible generation capacity for residential customers is limited to a maximum of 10 kW, and commercial customers are limited to 100 kW.[44] In the initial two-year phase of the net billing program, OUR has limited new capacity connections to 2% of Jamaica's highest demand peak in order to assess the impact to the JPS grid. The 2% cap will be evaluated and possibly adjusted or removed following this initial phase.[45]

The price that net billing participants receive is based on the short-run avoided cost of JPS (i.e., avoided fuel costs) plus a premium of up to 15%. JPS recalculates the rate every month, subject to OUR approval.[46] The net billing rate for June 2012 was set at approximately 20–21 U.S. cents per kWh of electricity sold to the grid based on this tariff-setting scheme.[47] Rather than receiving direct payment for electricity sent to the grid, the value is applied to the customer's electric bill as a credit or bill reduction.[48]

JPS has established a consistent framework for net billing customers through a Standard Offer Contract for the Purchase of As-Available Intermittent Energy from Renewable Energy Facilities.[49] JPS has elaborated the application process for entering into the net billing program.[50] (See Figure 8.2.)

MSTEM awarded the first 11 five-year net billing license contracts in May 2012, but so far only two

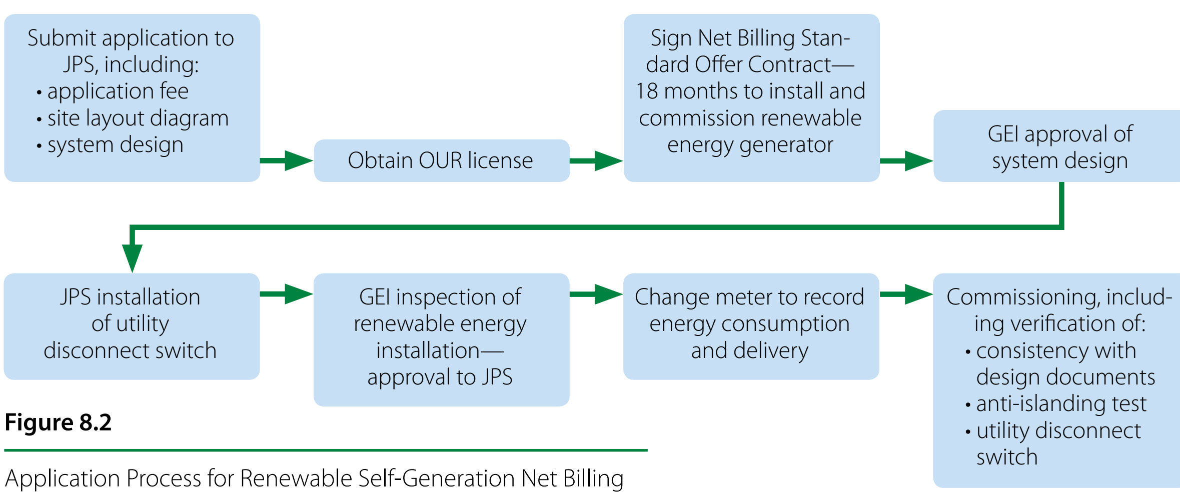


Figure 8.2

Application Process for Renewable Self-Generation Net Billing

Source: JPS
© Worldwatch Institute

customers have been connected to the grid. Cost barriers to participation in the program and low net billing rates have contributed to the lack of uptake to-date.

In addition to renewable energy equipment costs, JPS determined that self-generators will also incur a non-refundable net billing application fee, the cost of a new meter, and possibly costs for an impact study and interconnection infrastructure, if these are necessary.[51] JPS also requires insurance measures for commercial installations larger than 10 kW. According to some stakeholders, these requirements are prohibitive and exceed insurance standards for net billing and metering systems in other countries, and Jamaican insurance companies do not have the capacity to meet the requirements.[52]

A relatively stable net billing rate and availability of financing for these installations will be instrumental to the program's future success. In addition, modifying the tariff-setting mechanism in Jamaica to enact net metering rather than net billing based on avoided cost would further increase the incentive to install small-scale, decentralized renewable systems. Through net metering, customers would receive actual payments for electricity sales, rather than lowered electricity bills.

Electricity Wheeling

Electricity wheeling also was included in the updated JPS license last year, with the goal of increasing competition on the electricity market.[53] Electricity wheeling means that self-generators can pay JPS a fee to have the electricity that they generate moved to another point on the grid. Because JPS has monopoly rights over electricity sales, however, this power wheeling must be limited to one person or company.[54] For example, a sugar company could send excess generation from a bagasse plant in a rural area to its office headquarters in Kingston or other city. In contrast to net billing, which is aimed at small-scale generation, electricity wheeling is targeted at larger commercial- and industrial-scale installations.

The success of electricity wheeling in encouraging renewable self-generation and competition depends largely on the fee that JPS charges self-generators for wheeling services.[55] MSTEM Minister Paulwell criticized JPS in October 2012 for delays in implementing the wheeling measure and setting the customer fee.[56]

In May 2013, OUR released its second consultation document detailing recommendations for electricity wheeling methodology in Jamaica, including how to set fees for generators seeking to participate in the program. Ideally, the fee will reflect the cost to the transmission and distribution system of transporting electricity from these distributed users. OUR selected a "MW-km load flow" methodology, which uses a power flow model to calculate the cost to the power system of an individual electricity transaction. Despite OUR statements at a stakeholder consultation in early 2013 to the contrary, the wheeling program will include variable renewable energy, enabling the participation of solar and wind projects.[57] OUR was to begin accepting applications for the net wheeling program in August 2013.[58]

Several Jamaican companies have already expressed interest in taking advantage of the forthcoming electricity wheeling program, or stated that the measure would promote renewable energy—including solar and wind—and strengthen competitiveness in electricity generation. These companies include the Jamaica Boilers Group (the country's largest poultry producer), Seprod Limited (which operates the Golden Grove sugar estate), the hotel chain Sandals, Wisynco (a Jamaican food and beverage manufacturer and distributor), and the Solamon Energy Corporation (a solar power developer).[59] A National Irrigation

Commission project using wind energy to power irrigation pumps also has plans to participate in the wheeling program.

OUR Request for Proposals for New Renewable Generation Capacity

In November 2012, OUR released a Request for Proposals (RFP) for up to 115 MW of renewable generation capacity by 2015. Licenses for all new renewable generation plants between 100 kW and 60 MW must be obtained through the RFP competitive-bidding process (no single installation of greater than 60 MW will be eligible).[60] The previous non-competitive process that offered up to 10.73 U.S. cents per kWh for renewable capacity less than 25 MW is suspended while the current RFP is in effect.

Licenses under the RFP will be granted based on a competitive-bidding process, with preference given to renewable developers that provide low-cost bids. OUR set maximum tariffs for renewable generation based on technology. To be eligible to develop renewable generation capacity, developers must bid at or below these rates.[61] (See Table 8.2.)

Table 8.2. Maximum Tariff Rates for Renewable Energy Generation

Renewable Energy Technology	Maximum Tariff Rate
	U.S. cents per kWh
Utility-scale solar PV	26.73
Bagasse	15.16
Waste-to-energy	14.88
Wind	13.36
Hydro	11.13

OUR anticipates that 37 MW of the total 115 will be met with baseload capacity, adding 212 GWh of annual production to the national grid, and that the remaining 78 MW will be from variable renewable sources—referred to in the RFP as "energy only" plants—adding an estimated 205 GWh of annual generation.[62]

Winning bids enter 20-year initial contracts signed into power purchase agreements to sell power to the JPS grid.[63] OUR accepted applications through June 2013, and received 28 bids for new renewable capacity including two wind energy proposals, one biomass energy proposal, and 25 solar energy proposals. The combined capacity of these proposals is in excess of 500 MW. The short list of candidates was scheduled for release in September 2013. Construction on successful bids is expected to begin in May 2014, and OUR plans to commission the new capacity by May 2015.[64]

The RFP contains a number of provisions to ensure that it is attractive to potential developers. For example, tariff rates are remunerated in Jamaican dollars, but are indexed to the U.S. dollar. This provides greater investment security by shielding developers from the uncertainty and volatility that may be associated with the Jamaican economy and depreciation of the Jamaican dollar over the contract period.[65] In addition, contracts are formalized through 20-year power purchase agreements with JPS that include guaranteed grid access and dispatch.[66]

The RFP also contains several provisions to combat underbidding, breach of contract, and delays, which have historically plagued the success of renewable energy tenders in other countries.[67] (See Sidebar 4.) Applications will be evaluated based on the applicant's ability to implement the proposed project, including past experience, technical qualifications, and ability to raise financing.[68]

Despite some strong provisions and selection criteria, several aspects of the RFP pose a challenge

Sidebar 4. Safeguards and Barriers in OUR Selection Criteria for Renewable Energy RFP

OUR's RFP for 115 MW of renewable energy generation capacity includes several measures to ensure that the strongest bids are selected. First, it establishes comprehensive and rigorous evaluation criteria to select winning bids that make pricing secondary to other considerations. Bids proceed through a three-stage process, evaluated first on track record and qualifications, second on the technology used and reliability of the resource supply chain, and finally on a project's capacity, efficiency, and price.

Technical evaluation of project proposals will include consideration of the viability of the proposed technology, number of years that investment-grade data have been collected at the site, site suitability, and project design components. In the third stage, finalist bids are evaluated and winners are selected based on expected performance and performance guarantees, and firm capacity proposals are given priority over variable capacity. Only if the expected plant performance is similar between two bids will the winner be chosen based on price.

The RFP also mandates penalties for breaching the stipulations of the power purchase agreement to ensure that developers and contractors are held accountable for the performance of the projects and their completion in a timely manner—another challenge faced by other countries commissioning renewable energy capacity through competitive tendering. OUR's RFP provides for liquidated damages to be assessed against the developer for delays in commissioning, shortfalls in capacity, and failure to meet dispatch requirements.

For firm capacity proposals, contractors must be secured by a performance bond, and will be required to pay the damages assessed to the developer if the plant is not constructed on time or fails to meet performance guarantees. In addition, winning projects are required to submit a performance security deposit of 10% of the total expected capital cost prior to construction in order to attract bids only from well-established developers with sufficient financing to complete their projects.

The RFP requires applicants to undergo much of the permitting process for potential projects before submitting an application. Applicants must submit an initial environmental impact report with their bids, and a full environmental impact assessment prior to the commencement of construction. They are also responsible for all matters relating to the siting of projects, including obtaining necessary approvals from relevant agencies, arranging access and interconnection for the site, and paying for all the costs involved. These provisions are designed to ensure that the RFP only attracts companies with sufficient time and resources to undergo the permitting process for their projects.

Although these provisions aim to ensure selection of successful renewable energy capacity bids, there is a risk that some of these measures could backfire by being too restrictive and deterring potential bidders. In particular, acquiring all the necessary permits, assessments, and agreements before submitting a bid may be a complex, time-intensive, expensive, and confusing process for developers, especially for foreign firms.

Additionally, unlike most successful competitive tenders in other countries, which focus on one particular renewable energy technology, OUR includes multiple technologies in the same RFP, thereby setting different renewable energy sources in competition with one another. Because they are contending for a set amount of capacity with winners chosen based on price and technological feasibility, more expensive technologies are likely to be outcompeted. Along with the preference for fixed over variable generation, this risks decreasing the competitiveness of technologies such as solar PV, despite Jamaica's strong solar resources.

Source: See Endnote 67 for this chapter.

for its successful implementation. Although the RFP specifies that "the Licensee shall not be obliged to undertake extension of any transmission or distribution lines to deliver the power generated," the wording in other sections of the document is less clear.[69] In particular, the RFP stipulates that companies proposing variable (solar and wind) renewable energy capacity bids must include interconnection facilities—extended high-voltage transmission lines and substations—in the proposals, and that these companies "shall be solely responsible for all matters relating to the Project Site including access, interconnection and costs."[70]

Independent power producers—namely Wigton Windfarm—have borne these transmission and interconnection costs in the past, and they can be enough to render viable projects unprofitable.[71] Unless JPS is required to extend transmission lines to accommodate renewable capacity, IPPs will likely continue to bear this cost burden. This cost allocation is especially contentious as IPPs are required to turn over any transmission lines and substations that they finance to JPS for operations under the current transmission and distribution monopoly arrangement, as was the case with Wigton.

Additionally, some provisions and omissions in the RFP risk reducing investor confidence in Jamaica's competitive-tendering process. Instances of unspecified language in the RFP document could deter project developers from investing in the bidding process. At one point, the RFP states that the power purchase agreement may be terminated by either party "under certain specified conditions," but it never specifies what those conditions are.[72] Later, the RFP states that "certain tariff components may be indexed to reflect changes in costs faced by the Project Company that are due to factors outside its reasonable control," but it does not state what these components or factors are.[73] Furthermore, in addition to the proposal security deposit and performance security deposit, the RFP requires that a construction security deposit be posted; however, the terms and amount of this third deposit are never specified.[74]

There are several barriers to successful full implementation of the RFP, due to the nature of the RFP conditions and the status of the renewable energy market in Jamaica. Lack of adequate resource assessments and resource availability could pose a challenge, although PCJ's recent publication of its renewable resource potential and feasibility assessments signals a positive first step. The availability of municipal solid waste to fuel a waste-to-energy facility remains in doubt due to resource availability, despite years of interest in waste-to-energy on the part of the Jamaican government and private industry. Jamaica's National Solid Waste Management Authority has been slow to detail future plans for the country's waste management system, and it was unlikely that these would be resolved before the April 2013 deadline for applications under the RFP.[75]

It is also possible that the maximum tariff rates under the RFP are too low to incentivize investment. These maximum rates are based on a study commissioned for MSTEM to determine rates for a feed-in tariff for Jamaica. Therefore, setting these rates as the *maximum* tariffs in the tender means that the closing price at the end of competitive bidding will likely be *below* the optimized rate and may not be sufficient to cover costs and provide adequate returns. In addition, these rates do not include the costs of transmission and interconnection infrastructure that might be required for operators of variable wind and solar power plants.

Overall, the current RFP appears to be an effective measure to promote renewable energy growth in

Jamaica. However, Jamaica needs to ensure that this transition is both smooth and continuous to achieve greater future penetration of renewables into the electricity sector. In this light, OUR should reverse its suspension of non-competitive renewable capacity additions during the tendering period.

The tendering process already has been delayed by three months, with construction of projects now expected to begin in August 2014. With the suspension, this means that there is an almost two-year gap during which no new grid-connected renewable energy projects are expected. Furthermore, projects under the non-competitive system were offered at the avoided cost of generation plus a 15% premium (10.73 U.S. cents per kWh), which is significantly less than any of the maximum tariff rates under the RFP, so it is unlikely that the competitive and non-competitive systems would capture the same projects.

8.4 Recommendations for Future Sustainable Energy Policies

Jamaica's current competitive renewable energy capacity tender should yield important information about the demand to build renewable energy projects in Jamaica, optimal tariff rates, viability of and interest in different technology options, and the administrative burden on the government for support policies. Based on the results of the RFP, Jamaica has several different policy options to ensure continued expansion of the renewable power sector.

8.4.1 The Modernize Electricity Act

The process to develop formal electricity sector legislation began in 2004 but failed to progress without a broader energy policy. MSTEM is currently developing a National Electricity Policy and accompanying legislation, the Modernize Electricity Act, using the National Energy Policy for 2009 to 2030 as the larger framework for the legislation. The Cabinet must approve the Electricity Policy before the legislation can proceed to Parliament.

MSTEM hopes to address several existing barriers to renewable energy development through the Modernize Electricity Act, including bringing OUR's regulatory mandate for the electricity sector under the authority of the Government of Jamaica, and holding OUR accountable to this mandate. MSTEM also aims to take over the mandate for planning and procurement of electricity concessions and licensing from OUR.

The Modernize Electricity Act would also require a more formal and regular meter tariff review. In addition, it would provide a standard for off-take agreements for renewable energy projects.[76]

8.4.2 Ongoing Competitive Renewable Tenders

If the RFP successfully generates significant interest from high-quality bidders, Jamaica should consider continued tendering to achieve capacity additions from renewable energy. To avoid the potential pitfalls of this tender, future tenders should be technology specific so that, for example, wind projects compete only with other wind projects. The maximum tariff rates of future tenders should be adjusted based on the results of the current tender, which should provide a more accurate benchmark for ideal tariff rates. Minimum tariff rates should also be set as a further precaution against underbidding.

To achieve more ambitious and continuous growth of renewables using tenders, they must be issued on a frequent and regular basis. Although the greatest strength of tenders is that they are simple and involve relatively low administrative costs, this advantage may be undercut if the entire bidding and selection process must be repeated on an annual or biennial basis.

8.4.3 Feed-in Tariff System

Alternatively, feed-in tariffs create stable renewable energy markets by providing guaranteed payments per kWh for renewable energy generation, and have been one of the biggest drivers of renewable energy development worldwide. There is significant interest within the Jamaican government and private sector in a renewable energy feed-in tariff system. MSTEM and the World Bank recently completed a feed-in tariff study for Jamaica that determined appropriate rates for various renewable energy technologies, including: 11–15 U.S. cents per kWh for hydro, 14 U.S. cents per kWh for wind, and 26 and 32 U.S. cents per kWh for utility-scale and consumer solar PV systems, respectively.[77] These rates served as the basis for maximum tariffs allowable for bids under the OUR RFP.

As with competitive renewable energy tenders, feed-in tariff systems may involve significant upfront administrative costs to establish a program, but once it is created there is no need to go through the process of issuing RFPs and evaluating bids (although there is significant work involved in adjusting feed-in tariff rates to reflect changing market conditions and technology costs). Furthermore, there is no limit to capacity additions for renewable energy projects under feed-in tariffs, so an unlimited number of projects may enroll at the same price. Therefore, there is no underbidding, and risk is transferred from the government and OUR to the project developers to ensure that their projects succeed.

Although some entities, including JPS and OUR, have expressed resistance to a feed-in tariff by citing concerns over increasing electricity prices, Worldwatch's electricity cost assessment demonstrates that the cost of generation from most renewable energy sources is much lower than current JPS thermal generation. JPS should therefore be able to reduce costs by purchasing renewable electricity through a feed-in tariff system, and to reduce the price of electricity for consumers.

Feed-in tariffs are by no means a guarantee of successful renewable energy deployment, but they are generally considered the most successful and most widely used policy instrument across the globe.

8.4.4 Tax Credits

In addition to Jamaica's existing tax and import duty exemptions for energy efficiency and renewable energy equipment (described earlier), tax credits for renewable energy power plants can be instituted to further incentivize development. There are two main categories for these tax incentives: investment tax credits and production tax credits.

Investment tax credits (ITCs) are tax reductions for energy developers based on investments in capital equipment and installment. They can be an important way to reduce the burden of high upfront capital costs for renewable energy plants. Production tax credits (PTCs) are based on actual electricity generated. Proponents of PTCs favor the generation-based inventive approach because it encourages companies to operate renewable energy facilities to their fullest potential in order to receive the tax break. In contrast, ITC policies can allow companies to install renewable energy capacity and benefit from the tax reduction upfront, without ever operating the systems.

8.4.5 Guaranteeing Grid Access and Priority for Renewable Capacity

Requirements for grid strengthening and expansion to accommodate new renewable capacity—especially from distributed and/or variable sources—should be institutionalized and enforced. This should include regulation that mandates JPS to provide grid connection for renewable capacity and preferential grid access for renewable generation.

8.4.6 Strengthening Grid Equipment and Operating Regulations

In addition to new grid infrastructure, regulations for grid operations and technologies are needed to smoothly incorporate renewable generation. Jamaica's Bureau of Standards (BSJ) has developed standards and protocol for inverter systems; these should be implemented and enforced.

8.4.7 Loan Guarantees for Large-Scale Sustainable Energy Investments

As examined in Chapter 7, Jamaica's indebtedness and lack of established sustainable energy markets creates a high-risk lending environment, discouraging commercial international banks and even development-oriented lenders from providing renewable energy loans for projects in Jamaica. A sovereign guarantee from the Government of Jamaica to ensure that all loan payment obligations will be met if the project developer defaults would greatly reduce the risk of renewable energy investment in the country.

Although Jamaica's strained financial situation makes it difficult for the government to take on sustainable energy investment risk by itself, providing sovereign and other types of loan guarantees is one area where international assistance or climate finance can help strengthen Jamaica's energy market.

8.5 Summary of Policy Recommendations

Although the Jamaican government has developed a National Energy Policy through 2030 that includes energy efficiency and renewable energy goals, these targets should be significantly strengthened, applied to specific sectors, and adopted by all relevant actors. A strengthened platform for mainstreaming targets and policy measures across all relevant government agencies is needed and should be coordinated through the existing Jamaica Energy Council.

In addition, the country's electricity regulator, OUR, needs to be held accountable to its mandate to increase renewable energy capacity and ensure affordable electricity prices. As a first step, OUR should fully and effectively implement its current RFP for 115 MW of new renewable capacity in Jamaica. Following the selection of renewable projects through this competitive-bidding process, planning and procurement of new electricity capacity should be relegated to MSTEM either through a continuation of the current RFP process if the current phase proves successful, or through alternative policies such as a feed-in tariff.

9 | Jamaica's Energy Outlook: Transitioning to a Sustainable Energy System

As demonstrated throughout this Roadmap, Jamaica has tremendous potential for transitioning to an efficient, affordable electricity system powered by renewable resources. To realize the economic and environmental benefits of sustainable energy, Jamaica can implement several policy measures and reforms that help to create a stable investment environment for energy efficiency and renewable energy projects.

Throughout this Roadmap, Worldwatch has identified key research gaps, capacity building needs, and areas for policy reform that should be addressed in the coming years to support a smooth and well-informed transition to a sustainable energy system. All of these challenges can be tackled in the near term, and many essential steps can be taken immediately. (See Table 9.1, next page.)

In addition to the important measures that Jamaica's government, private sector, academic institutions, and non-governmental organizations can undertake internally, participation in regional and international sustainable energy initiatives can strengthen the country's ambition and resources for reducing energy intensity, increasing renewable energy capacity, and reducing greenhouse gas emissions.

As a member of the Caribbean Community (CARICOM), Jamaica signed on to regional sustainable energy targets in March 2013. In addition, Jamaica is a key participant in the Low Emission Development Strategies (LEDS) Global Partnership program, which promotes best practice and information exchange between countries for reducing greenhouse gas emissions, including through energy sector measures. Through the LEDS program, Jamaica will develop a national Climate Change Strategy to complement its National Energy Policy.[1]

Jamaica's government, private industry, and civil society have acknowledged the important role of energy efficiency and renewable energy in reducing energy costs, bolstering the national economy, and contributing to a healthier environment. The country is now at a crucial point where it must implement targeted measures and reforms in order to achieve the full benefits of a sustainable energy system in the coming years.

Table 9.1. Next Steps for Jamaica's Sustainable Energy Transition

Step	<1 Year	1–2 Years	3–5 Years
Conduct Additional Technical Assessments			
Assess energy and cost-savings potential of bauxite/alumina efficiency standards	●		
Conduct sector-wide efficiency study for hotel/tourism industry to demonstrate cost savings	●		
Determine key appliances for new/upgraded efficiency standards	●		
Conduct feasibility assessments for utility-scale solar PV farms	●	●	
Conclude Wigton site-specific wind resource and feasibility assessments, including variability data	●		
Conduct up-to-date small hydro resource and feasibility assessments	●	●	
Conduct thorough resource and environmental assessment of biogas vs. direct combustion waste-to-energy	●		
Conduct grid connection feasibility and cost assessments for solar, wind, and small hydro sites	●	●	
Conclude World Bank grid assessment; include feasibility and cost assessment for connecting and integrating distributed and variable renewable generation	●		
Conduct site feasibility assessments for pumped-storage hydro	●	●	
Strengthen Socioeconomic Data Availability			
Centralize Jamaica-specific renewable energy job creation data		●	
Assess gender inequities with regard to access to sustainable energy wealth and job-creation opportunities in Jamaica		●	
Strengthen Financial Institutions			
Continue and expand education campaigns to improve risk perception for sustainable energy investment	●	●	●
Establish sovereign guarantee for sustainable energy loans with support from development institution		●	
Establish national strategy for accessing climate finance, including through Nationally Appropriate Mitigation Actions	●	●	
Implement Strong Policy Framework			
Focus Jamaica's energy strategy on renewable energy; coal and natural gas should be secondary	●		
Establish stronger, sector-specific renewable energy targets	●		
Strengthen the role of the Jamaica Energy Council in fostering inter-ministerial cooperation for sustainable energy	●		
Enforce OUR's mandate to ensure affordable electricity from renewable sources	●	●	●
Pass legislation to grant MSTEM authority over electricity capacity planning and procurement	●		
Streamline permitting procedures for renewable energy projects	●	●	
Implement energy efficiency building standards	●		
Pass new appliance efficiency standards		●	
Expand electricity theft audits and automated meter installations	●	●	●
Ensure full participation in net billing and electricity wheeling programs	●		
Implement renewable capacity request for proposals in a timely, efficient manner	●		
Establish mechanisms for future renewable capacity procurement, possibly through net metering and feed-in tariffs		●	
Guarantee grid connection and priority grid access for renewable capacity	●		

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Appendix I. 3TIER Solar and Wind Assessments

Jamaica

27 November, 2012

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Contents

1 EXECUTIVE SUMMARY

This is the final report for the wind and solar resource assessment of Jamaica performed under contract by 3TIER for the Worldwatch Institute. For this project, separate analyses were performed for 10 zones within the country: 3 zones were examined for their wind resource characteristics, and 7 for their solar resource. For the wind zones, several points were chosen inside each zone so as to represent the distribution of a potential wind farm project. The data in this report for each zone represent the mean data across all points in that zone. For the solar zones, a single representative point was chosen to perform the resource assessment. Separate reports have been issued for each wind and solar zone; this report summarizes the findings of the individual reports, and discusses some aspects of the aggregrate wind and solar resources.

Because of the mountainous nature of Jamaica, and its partial exposure to the North Atlantic trade winds, there is a wide range of wind potential across the country. In contrast, the solar resource is relative uniform. Both technologies offer the potential for development from a pure resource perspective.

There have been many assumptions made during the course of this study, as discussed in the body of work, and the analysis does not take into account some serious considerations (planning approvals, land owner agreement, land availability, technical issues with integration and transmission, financial viability, etc.). These issues could reduce the number of viable sites considerably, but such considerations were outside the scope of this project and all calculations have been made under the assumption that, within the zones provided by the Worldwatch Institute for study, all land is available for development.

2 OVERVIEW

2.1 Introduction

The deliverables agreed upon in the scope were designed to assess Jamaica's wind and solar potential for macroscopic transmission planning studies. To achieve this goal, the bulk energy capability was examined for 10 zones in Jamaica (7 for solar, 3 for wind), and this report will attempt to address the the results of these analyses, primarily from an aggregate perspective. This report includes a comparison of the average diurnal and monthly/seasonal cycles for each region. Additional zone-specific information is available in the previously delivered per-zone reports.

2.2 Project Approach and Assumptions

A key consideration in this type of project is a clear understanding of the approach used and the assumptions that were made. The scale and scope of this project preclude detailed investigation of specific locations and potential projects; instead the focus was placed on effectively modeling the wind and solar resources across the regions of interest (zones) provided by the Worldwatch Institute, and on representing their general characteristics to facilitate future analyses of a more focused nature. Here, we will explain the general approach that was taken, for both the wind and solar assessments undertaken as part of this project, to characterize the resource in each zone given the constraints mentioned above.

2.2.1 Wind

To analyze the wind resource, 3TIER configured and ran a mesoscale Numerical Weather Prediction (henceforth abbreviated as NWP) model over Jamaica, over the period spanning January 1987 through June 2012. The length of this modeled data set was chosen to provide a view into the long-term resource variability characteristics across Jamaica. Due to the nature of the project, no observed data were available for Model Output Statistics (MOS) adjustment of the raw NWP model output, and therefore it should be understood that the data shown in this report represent raw model output only.

For the wind portion of this project, 3 zones were provided by the Worldwatch Institute. A map showing the locations of the 3 wind zones, and the long-term wind resource at 80m across Jamaica, can be seen in Figure 1. The wind resource analysis performed by 3TIER attempts to characterize the wind resource for each zone; to this end, a set of points was chosen inside each zone to represent the characteristics of the wind resource across the zone. While the locations of these points may in some cases coincide with potential wind farm development, they should not be interpreted as being strictly representative of a hypothetical wind farm, as a detailed siting analysis was not within the scope of this project. Rather, they were chosen simply to characterize the wind resource that a wind park built in that zone could be expected to encounter. Additionally, it should be noted that no analysis of potential wake losses was performed.

As per the scope of the project, an analysis of potential generated power was performed using the raw modeled wind speeds from the Numerical Weather Prediction (NWP) model. After a preliminary analysis of the wind resource across each zone, the Vestas V112 turbine, with a hub height of 80 meters, was chosen as a turbine model appropriate for general use across all the zones considered for hypothetical wind park development. The manufacturer's power curve for this turbine (Vestas V112) was therefore used for all wind power/capacity factor analyses presented in this report. Appendix A describes the power curve.

One of the specified zones is the area 20km offshore, and for this zone the same power curve for the Vestas V112 was used unmodified due to the specialized nature of offshore wind turbines and difficulties in acquiring a suitable dedicated offshore power curve. It is believed that the Vestas V112 curve used provides an excellent representation of a potential offshore project, given the general nature of this study.

2.2.2 Solar

The solar resource analysis performed by 3TIER attempts to characterize the solar resource in each zone. Considering the base dataset has a 3km resolution, a single point was chosen inside each zone to best represent the characteristics of the solar resource across the zone. Each single location represents a center point of a grid in 3TIER's solar dataset. In most zones, the single point selected was near the center of the zone, but for some zones right along a coast, the point selected was shifted inland so that the grid box represented was largely over a land surface. Additionally, the single point selected was chosen with mean zone elevation in mind. While the locations of these points may in some cases coincide with potential solar plant development, they should not be interpreted as being strictly representative of a hypothetical solar plant, as a detailed siting analysis was not within the scope of this project. Rather, they were chosen simply to characterize the solar resource that a solar plant built in that zone could be expected to encounter. Additionally, it should be noted that no analysis of potential losses of any kind was performed.

As per the scope of the project, an analysis of potential generated power was performed using modeled solar irradiance, and raw modeled wind speed and air temperature from a Numerical Weather Prediction (NWP) model at a single point in each zone. An Aleo Solar S16 175 (2007E) module was chosen as a module appropriate for general use across all the zones considered for hypothetical solar plant development. The Aleo Solar S16 175 is a high quality module, and rigorous testing was performed on it by Sandia National Labs. The Sandia PV Array Performance Model was run independently for every hour of the data set, using a fixed set of parameters describing a single PV module and its installation angle. 3TIER chose a south facing module, with a fixed tilt from horizontal of 14 degrees as optimal for all zones in Jamaica. 3TIER's estimation of module output does not include any exterior losses, and assumes the module is at all times operating with a current draw that extracts the maximum power from the module. The results should be considered indicative of the output of a single array module operating in isolation under ideal management.

3 ANALYSIS OF WIND RESOURCE

3TIER performed an analysis of the wind resource in each of 3 zones specified by the Worldwatch institute, and this section presents a side-by-side analysis of the characteristics of the wind resource in each zone. The data presented here for each zone represent mean statistics across several points in that zone; these points were not chosen to represent an actual wind farm, but instead were chosen to best characterize the wind resource throughout the zones. A map showing the locations of the 3 wind zones, and the long-term wind resource at 80m across Jamaica, can be seen in Figure 1.

The data here, unless otherwise noted, represent statistics computed on the long-term modeled wind resource, averaged for each zone across all the studied points.

In addition to long term mean production of a hypothetical wind energy project in each zone, diurnal and seasonal cycles of the wind resource were considered. Distinct patterns were seen across all the zones, and here we will compare those signals and determine whether or not there are complementary patterns of variability present that could inform the development of multiple wind farm projects in Jamaica. Subsections 3.1 and 3.2 present an analysis of the diurnal and seasonal variability, respectively, of wind speed and gross power production.

Table 1 below shows an overview of the mean modeled wind speed and power production in each zone. These values suggest that, at least in the zones provided by the Worldwatch Institute, Jamaica has a strong wind resource that may be suitable for wind farm development. Conditions across all the zones were rather uniform, with high wind speeds and correspondingly high gross capacity factors, all above 50%. However, the locations of the zones and nature of the surrounding terrain and land cover vary, and some particular points should be considered for each:

- The Retrieve zone is situated roughly on top of a large ridge, which leads to high wind speeds and makes it a prime candidate for wind farm development. The surrounding area is also developed, and the proximity of roads and other infrastructure may make for more economical installation options.
- The Portland Parish zone, as specified by the Worldwatch institute, covers the mountain range at the northeast corner of Jamaica, at the eastern end of the Portland Parish. In this zone, points were chosen for analysis that are generally at higher elevations, making for high wind speeds and capacity factors which suggest that the zone may be suitable for wind farm development. However, unlike Retrieve, the area does not appear to be well-developed, which may make wind farm development in this area prohibitively expensive. Additionally, its exposed location on the eastern end of Jamaica may mean heightened exposure to destructive tropical storms, though such an analysis is outside the scope of this report.
- The third zone specified by the Worldwatch Institute is the area approximately 20km offshore of Jamaica, surrounding the entire island. 3TIER's simulations showed greater wind speeds in the offshore areas northwest and southeast of the island, so the points chosen for the zonal analysis are clustered in these areas. Wind speeds were (as is typical for an offshore site) high enough to consistently produce power at levels similar to the onshore zones specified, and additionally showed a relatively flat diurnal cycle (see subsection 3.1 for more details). However, it should be noted that since Jamaica frequently experiences tropical storms, offshore wind power installations may be subject to destructive weather events much more frequently than offshore installations in other parts of the world, and as such Jamaica may be unsuitable for offshore development. As before, though, an analysis of extreme weather events is beyond the scope of this report.

Also shown in table 1 are "net" capacity factors, computed simply by multiplying the "gross" (raw simulated) capacity factors by a loss factor of 0.85 (15% loss). A detailed analysis of losses is beyond the scope of this report, so this factor was chosen to represent all the losses (wake, electrical, etc.) that a hypothetical wind farm might experience, based on 3TIER's experience in modeling power production around the world. It should be interpreted only as an extremely rough estimate.

As is the case throughout this report, it should be noted that no on-site observations were available to validate or adjust the model output; as such, all the data presented here represent raw model output only and carry a high degree of uncertainty. If development of wind energy projects in Jamaica is going to be seriously considered in the future, it is 3TIER's recommendation that at least a year of meterological data be collected in order to reduce the uncertainty associated with raw model output.

Zone Name	Wind Speed ($\frac{m}{s}$)		Gross Capacity Factor (%)		Net Capacity Factor (%)	
	80m	100m	80m	100m	80m	100m
Offshore	8.41	8.50	53.2	54.2	45.2	46.0
Retrieve	8.60	8.56	50.0	49.6	42.5	42.1
Portland Parish	9.76	9.87	59.6	60.4	50.6	51.4

Table 1: Zone-by-zone overview of long-term mean modeled wind speed and capacity factor.

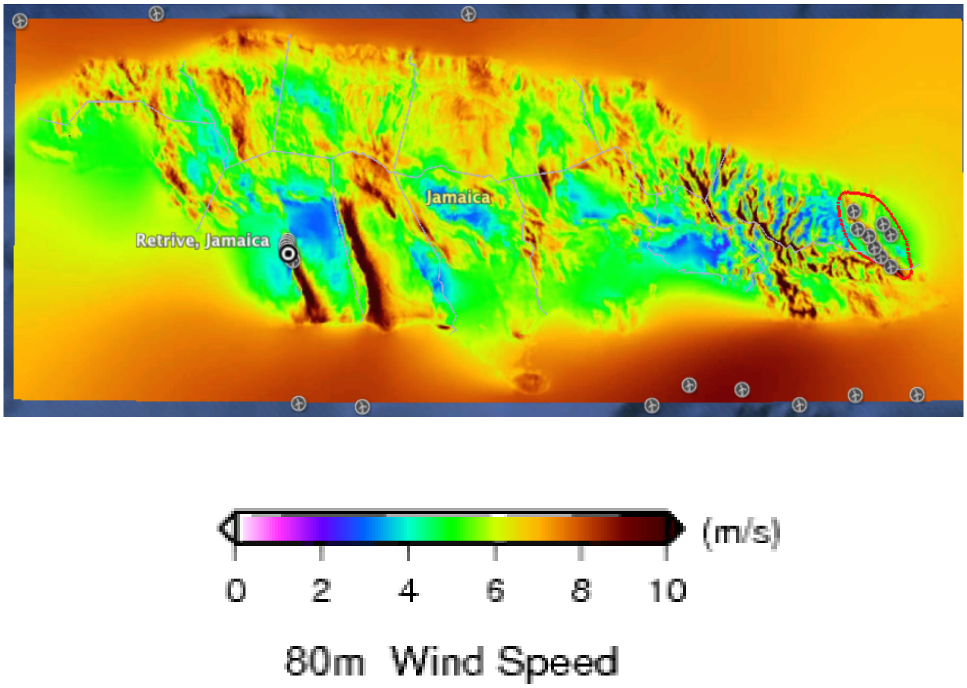


Figure 1: Map of the long-term modeled 80m wind resource over Jamaica. Points are marked by the small wind turbine symbols, and the Portland Parish zone is outlined in red.

3.1 Diurnal Variability

Figures 2 and 3 show the diurnal cycles of wind speed and capacity factor, respectively, for each zone specified for study by the Worldwatch institute. A quick examination of these figures reveals that the zones are experiencing a variety of different wind regimes.

From the data presented here, we can see several items that may be of interest to prospective wind energy developers:

- As expected, the mean diurnal cycle of the offshore points is relatively flat and consistent, suggesting a wind resource that will be available throughout the day. The Portland Parish zone has a diurnal cycle similar to the offshore points, but with a much more pronounced afternoon bump.
- Though Retrieve's diurnal cycle has a much more pronounced dip early in the day, its strength in the evening and peak slightly later than the other two zones may make it an ideal candidate for generating power during the evening hours when demand is typically high.
- The similarity of the offshore and Portland Parish zones is most likely due to the Portland Parish points' proximity to the coast, while Retrieve is further inland and more likely to experience different (and perhaps complementary) conditions.

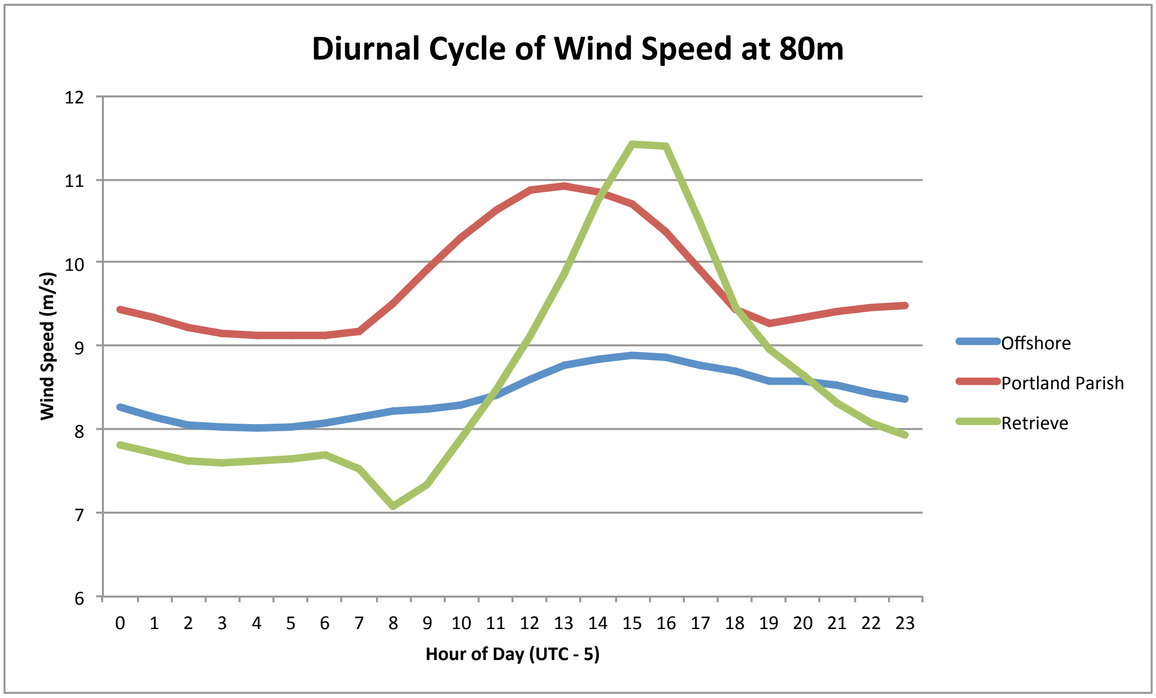


Figure 2: Diurnal variability of 80 meter wind speeds for each zone

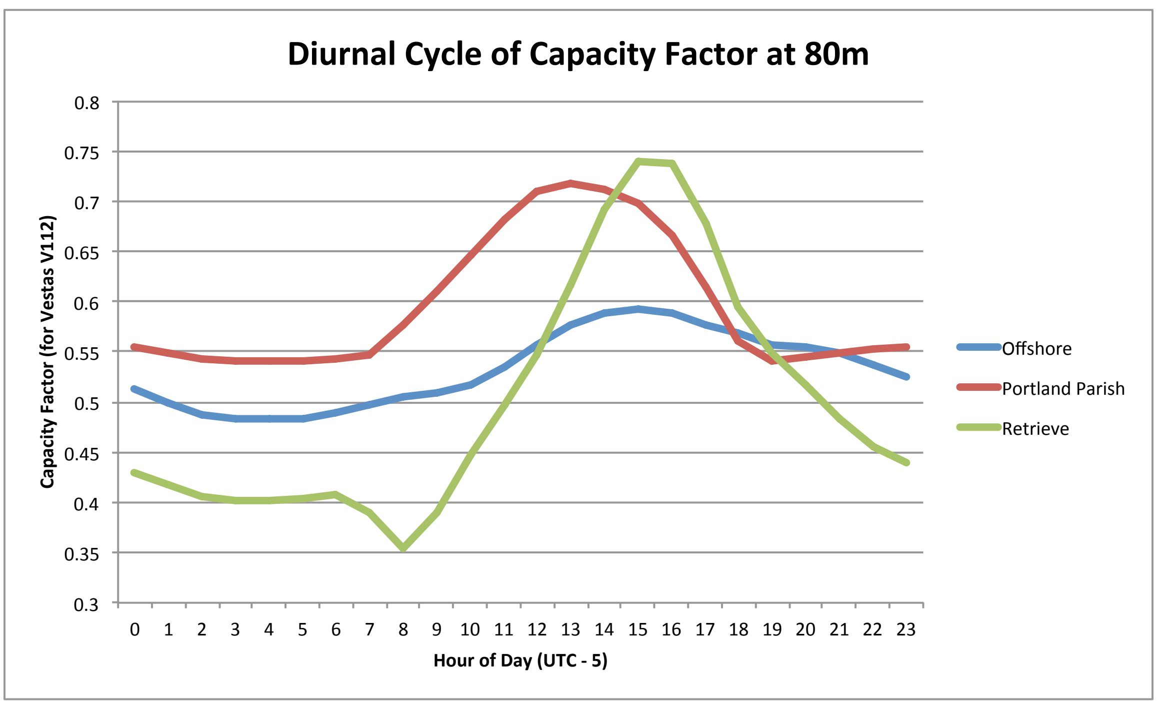


Figure 3: Diurnal variability of 80 meter capacity factor for each zone

3.2 Seasonal Variability

Figures 4 and 5 show the seasonal cycles of wind speed and capacity factor, respectively, for each zone specified for study by the Worldwatch institute. The most prominent features are the two peaks, one in winter and a second, lower peak during the summer months. Depending on Jamaica's particular power generation needs, this may be of interest to potential wind power developers.

Also of interest is the fact that all the zones' seasonal cycles follow more or less the same shape. Given that the zones chosen are relatively distant from each other, it is reasonable to expect that most other potential wind development sites in Jamaica would share the general characteristics of the seasonal cycles shown here.

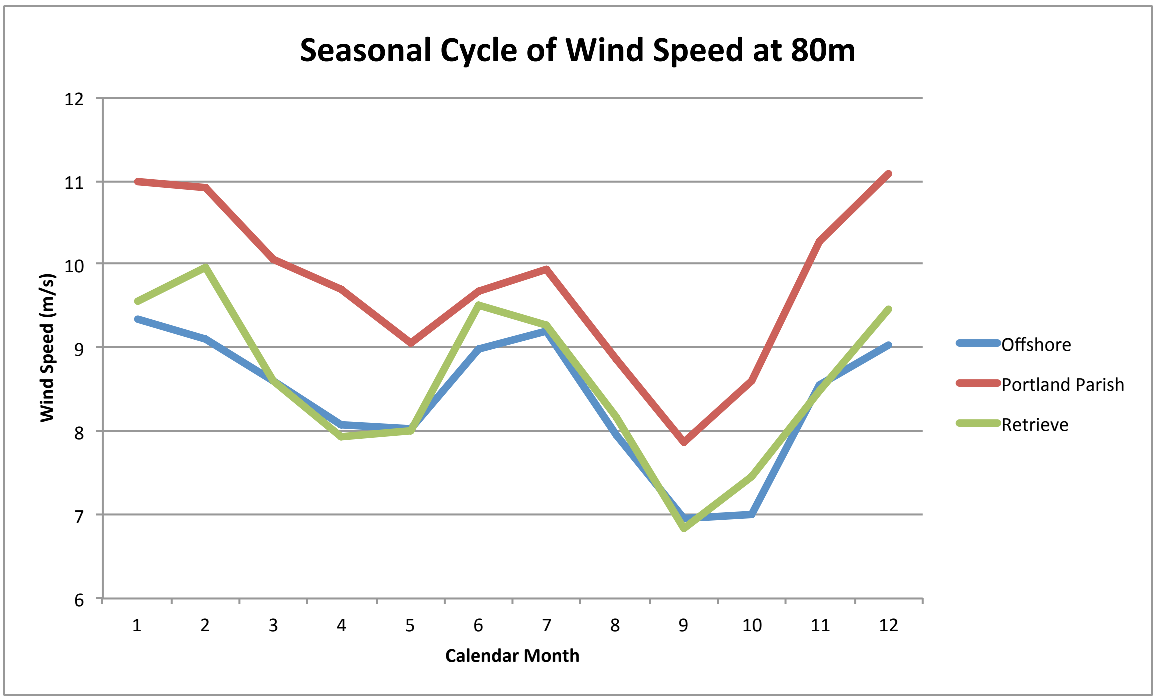


Figure 4: Seasonal variability of 80 meter wind speeds for each zone

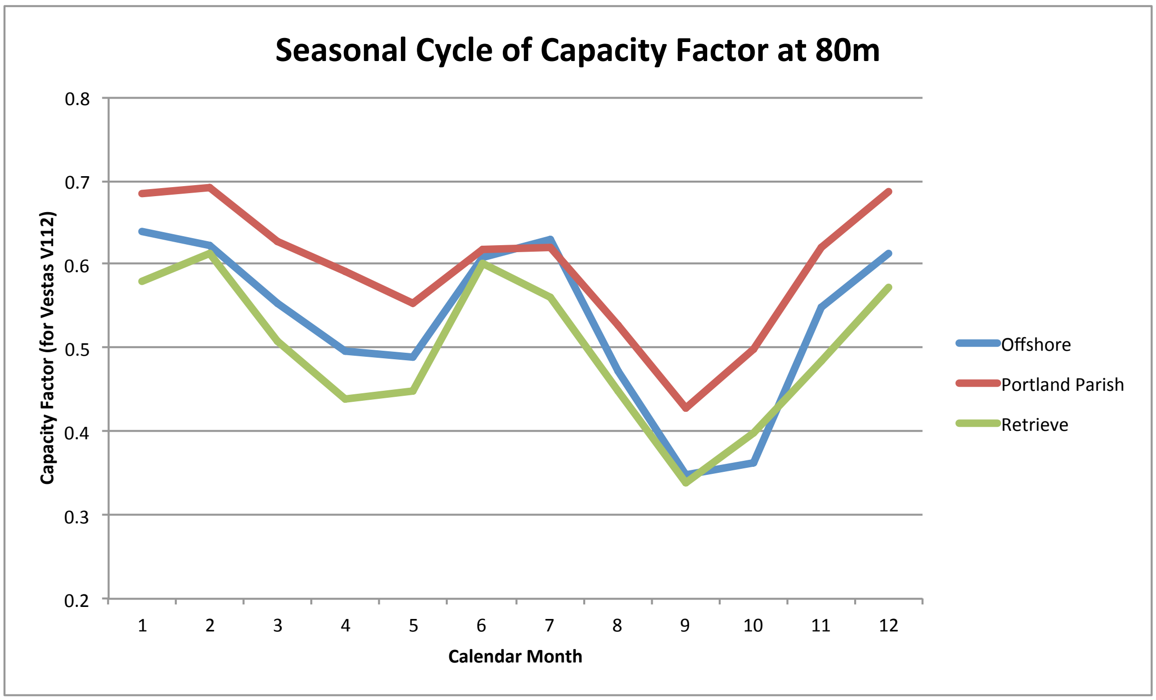


Figure 5: Seasonal variabity of 80 meter capacity factor for each zone

4 ANALYSIS OF SOLAR RESOURCE

4.1 Overview and Methodology

3TIER performed an analysis of the solar resource at 7 locations specified by the Worldwatch Institute. The locations are shown in Figure 6 and geographic coordinates are displayed in Table 2.

Analysis consisted of two parts. In the first, the annual average solar insolation was evaluated, together with inter-annual, monthly, and diurnal variation. In the second, the observed annual average insolation was used to estimate the annual output of a single solar module tilted at the latitude angle. The results from both parts are described in detail in the individual reports produced for each site.

Site	Longitude	Latitude
Montego Bay Convention Center	18.520743	-77.821321
St. Ann's Bay Hospital	18.436362	-77.210692
PCJ Building	18.011277	-76.788396
Soapberry Treatment Plant	17.999926	-76.868868
SRC Building	18.018728	-76.749537
Tradewind Citrus	18.105066	-77.00958
Wigton Wind	17.916227	-77.537157

Table 2: Summary of site locations

4.2 Results

The purpose of this report is to compare the seven sites to each other, to solar sites elsewhere in the world, and to the wind resources detailed in Section 3 above. As seen in Table 3, the solar and meteorological conditions at the seven sites are virtually identical.

This similarity is to be expected given the similarity in climate between the sites. Since the sites have virtually identical properties, we will focus the rest of our discussion on Tradewind Citrus. The variation in annual GHI and DNI at this site are shown in Figures 7 and 8.

The two components of irradiance track closely. The values of GHI are about 20% higher than DNI, which is an unusually large difference for sites in the tropics. At mid-latitudes, DNI typically exceeds GHI. This distinction has a consequence for power production on Jamaica. Concentrating utility-scale solar power systems (such as the parabolic trough systems seen in desert areas) depend largely on the DNI component of the solar resource, whereas PV responds more directly to variation in GHI. Jamaica thus appears to be substantially less suited for concentrating solar power than for photovoltaic generation. The individual site report for Tradewind Citrus gives the inter-annual standard deviation as 5% for GHI and 9% for DNI. However these numbers should be treated with caution because the distribution of annual insolation is notably non-normal. See the site reports for details. Monthly variations during the annual cycle are also nearly identical at all seven stations. The seasonal variability of each component of irradiance at Tradewind Citrus is shown in Figure 9. Power production for a photovoltaic plant approximately tracks GHI, so we can expect that the seven study sites will produce about 30% more power in the summer months then in the winter months. This modest increase is again consistent with the tropical location. Finally we examine the diurnal variation of irradiance, show in Figure 10 broken out by month. This figure too shows the pattern expected for a tropical site with smooth variation throughout the day. DNI and GHI are comparable in December when the sun is low in the sky, and fairly distinct in June when the sun is high. All sites show a distinct decrease in the DNI component in the afternoon. This appears to be the result of afternoon cloudiness at most sites.

Figure 6: Locator map for the Worldwatch Jamaica solar sites

Site	GHI $(\frac{W}{m^2} \cdot day)$	DNI $(\frac{W}{m^2} \cdot day)$	DIF $(\frac{W}{m^2} \cdot day)$	Wind Speed $(\frac{m}{s})$	Temperature (C)	Gross Annual Yield (kWh)
Montego Bay Convention Center	222.7	195.1	85.3	4.90	27.0	372.8
St. Ann's Bay Hospital	216.9	184.3	86.9	4.10	26.2	361.5
PCJ Building 218.9	188.4	88.0	2.8	26.10	363.4	0.0
Soapberry Treatment Plant	229.4	207.8	83.3	2.40	26.6	379.0
SRC Building	214.0	179.7	90.2	1.80	25.3	353.6
Tradewind Citrus	208.9	169.0	90.8	1.90	25.3	340.8
Wigton Wind	223.2	193.9	88.4	7.90	21.9	388.3

Table 3: Summary of annual average insolation and meteorological parameters

4.3 Discussion and Summary of Solar Results

The results described here and in the site reports have some consequences for the development of solar power in Jamaica. The major conclusions are:

- All studied sites in the country are capable of supporting utility-scale (grid connected) solar power generation using

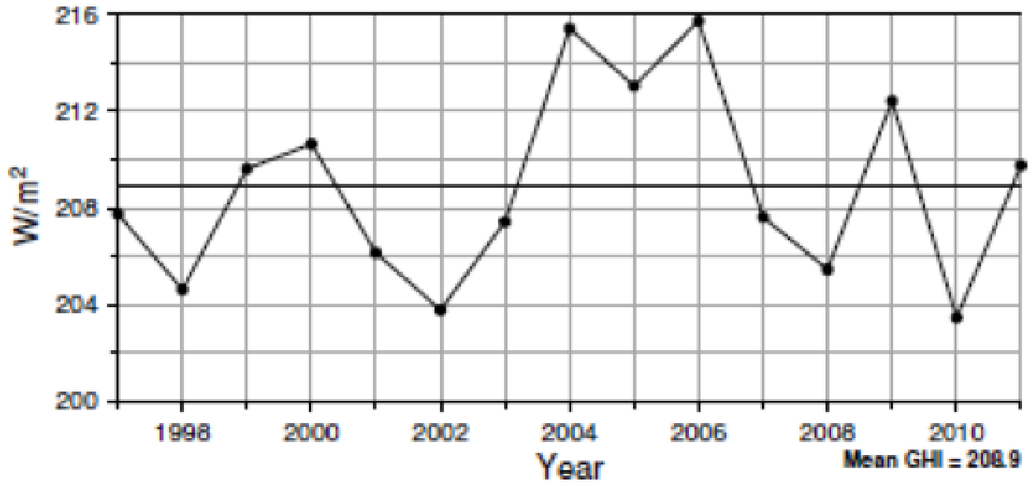


Figure 7: Annual average GHI irradiance at Tradewind Citrus over the 15 year data set.

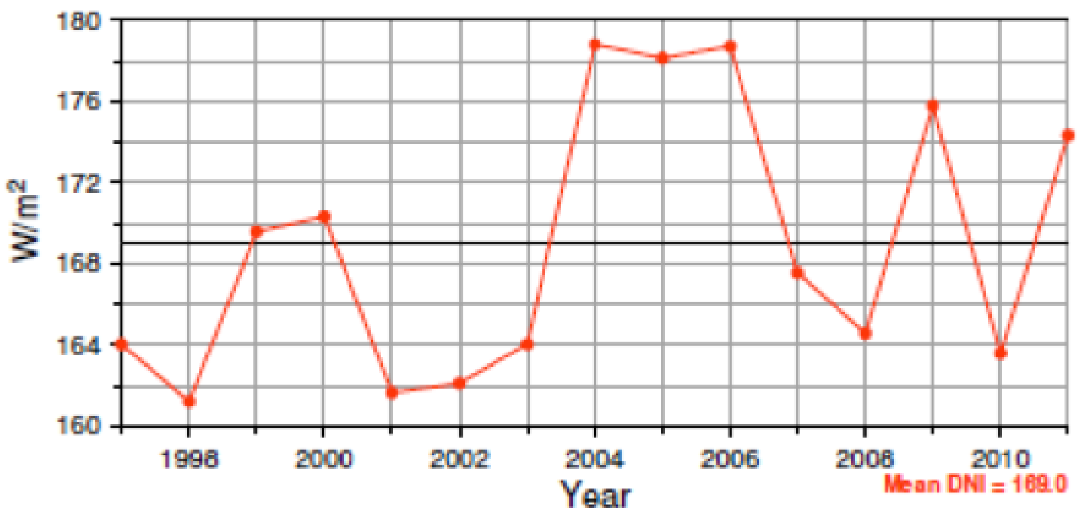


Figure 8: Annual average DNI irradiance at Tradewind Citrus over the 15 year data set.

photovoltaic technology.

- The sites are probably unsuitable for thermal (concentrating) solar electric generation.
- The solar resource at all sites is suitable for residential solar water heating. A fairly small solar module package could, for example, power a water pump.
- The solar resource at all sites is suitable for residential or small commercial PV (non-grid connected) generation.
- Inter-annual variability of solar power may be of concern for utility-scale operations, but should not significantly affect residential or small commercial power generation or water heating.
- A direct comparison of solar and wind resource is limited by the difference in location between the three wind study zones and the seven solar study zones. In general, the diurnal variability of the wind resource in Jamaica shows the primary wind resource at the Offshore and Portland Parish sites is during the daytime hours. This is also the pattern

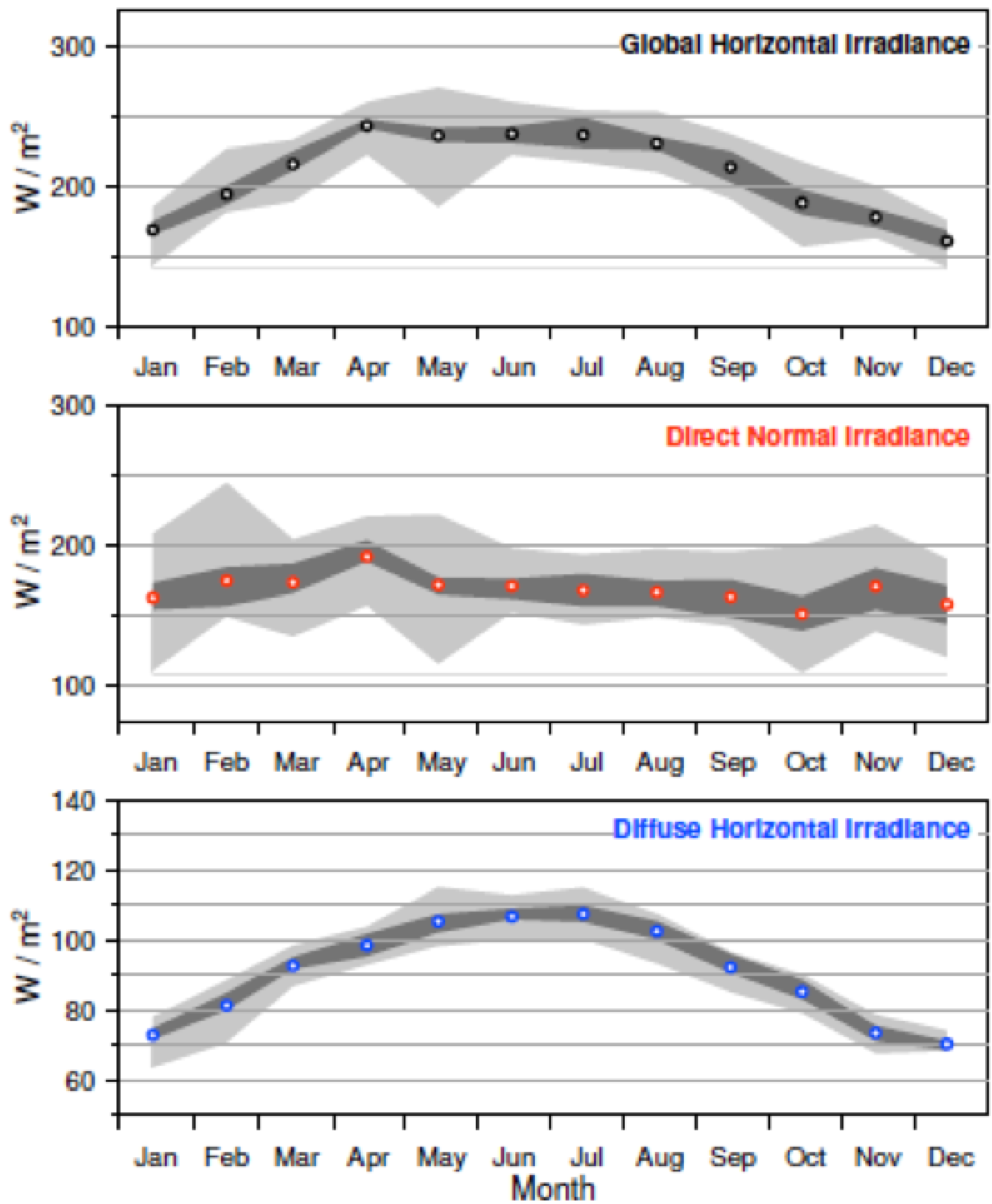


Figure 9: Seasonal variation of irradiance by component at Tradewind Citrus.

seen for the solar resource. This means that the complimentary night/day pattern of wind/solar resources seen at many locations – and potentially exploitable for joint production – is not present in Jamaica.

- Wind speed peaks in mid-Winter, with a smaller peak mid-Summer and lower Spring and Summer seasons. This pattern is only partly complimentary to the solar resource which peaks in summer and is at its lowest in winter. Still, this pattern might be exploited for joint wind/solar production under the right circumstances.

- As in most countries, the primary factors limiting the use of solar power in Jamaica are not meteorological, but infrastructure related. The availability of land and access to transmission capacity are the primary impediments to solar development. Jamaica has a fully built-out and mature electrical infrastructure with a number of electricity providers. Regional shortages in transmission capacity exist and must be considered when identifying suitable locations for solar development.
- From the standpoint of high solar resource, availability of transmission resources and land availability, the Wigton Wind site appears to be particularly well suited for development.

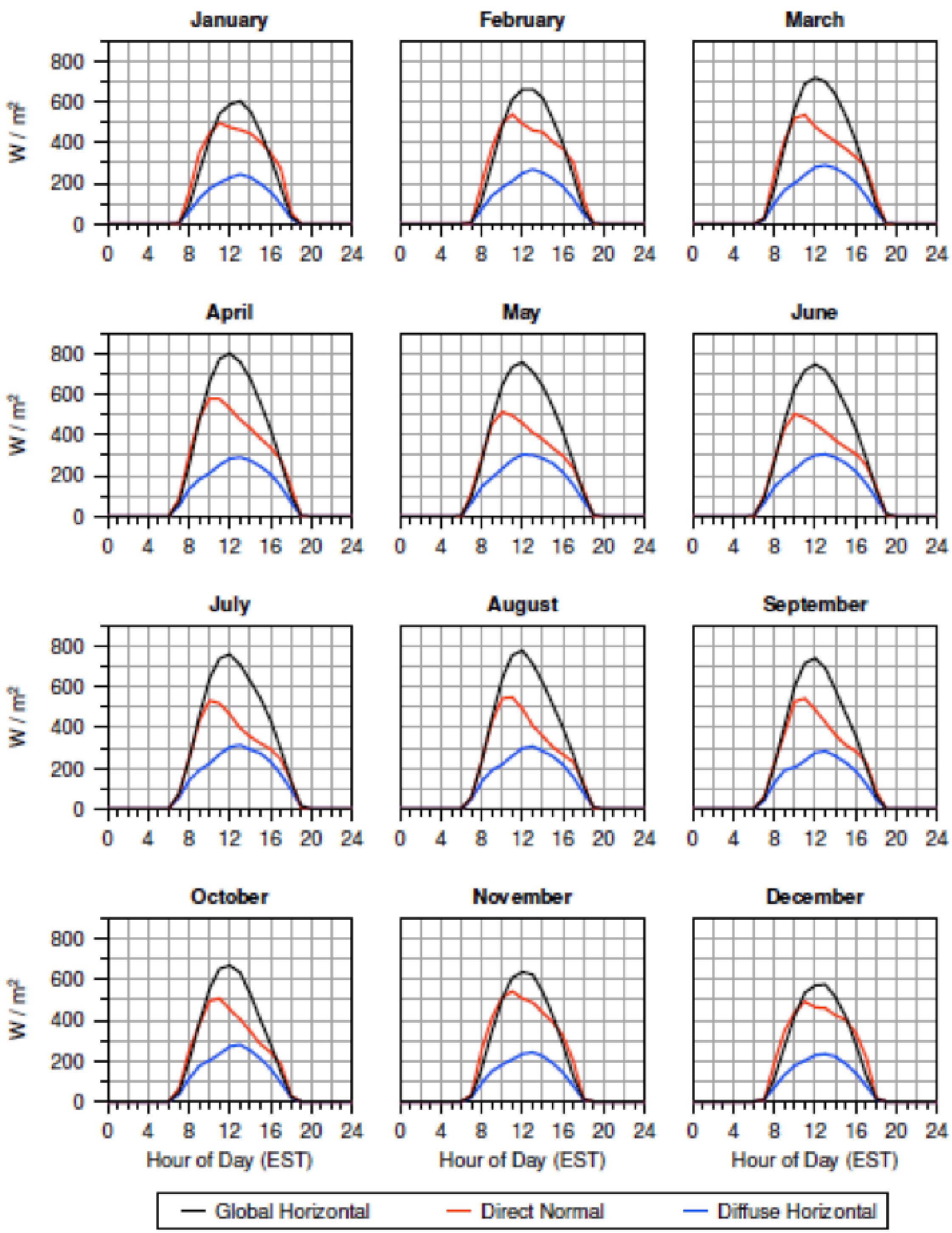


Figure 10: Diurnal variation of solar insolation.

A POWER CURVE FOR THE VESTAS V112 TURBINE

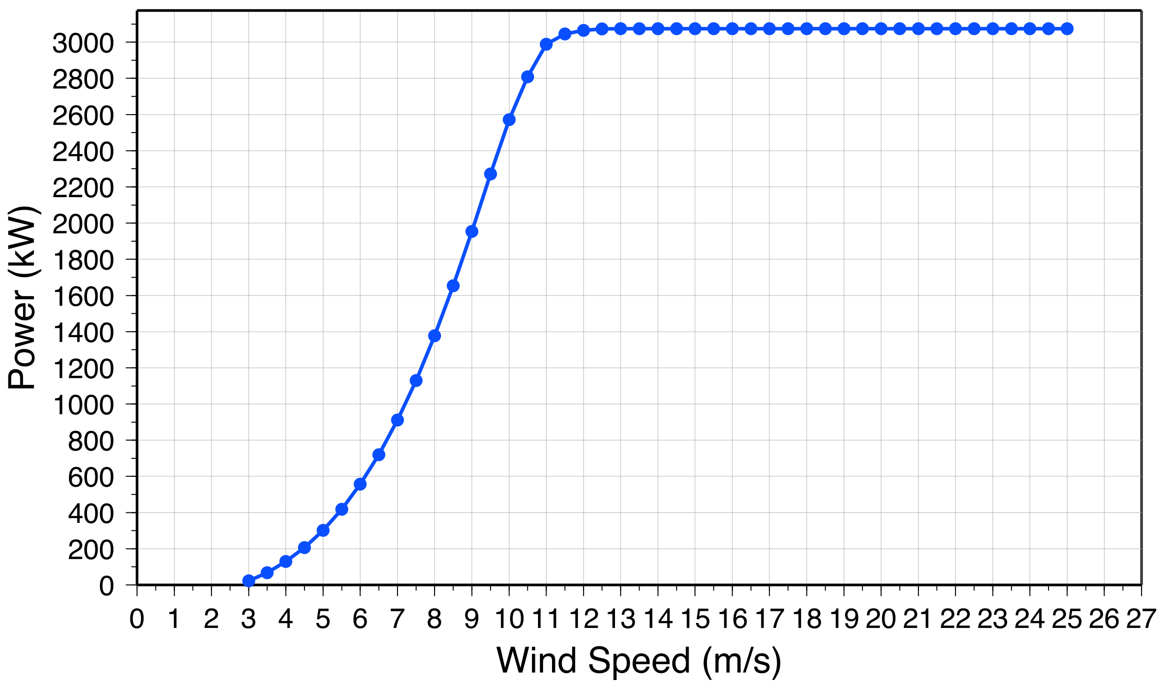


Figure 11: Power curve for the Vestas V112 turbine

Appendix II. Past and Ongoing Renewable Resource Assessments

Selected Past Assessments of Jamaica's Renewable Energy Potential

Resource	Organization Conducting/ Funding Assessment	Date of Assessment	Location	Resource Estimation
Solar	University of the West Indies (Dr. A. A. Chen)	1994	Country-wide	4.1–5.6 kWh per m^2 per day
Solar water heating	Solar Dynamics	2005	Country-wide	3–4 m^2 systems can meet household needs by saving 75,000–100,000 MWh per year
Wind	Petroleum Corporation of Jamaica	1995	Several sites country-wide	At least three sites in addition to Wigton with resource suitable for 20 MW wind farm
Small hydro	United Nations Economic Commission	2004	11 sites country-wide	33.4 MW
Small hydro	Not available	1995	Rio Cobre	4.45 GWh annually
Small hydro	GTZ and CREDP	2004 to 2005	Laughlands Great River	1.3 MW; 8.44 GWh annually
Biomass (bagasse)	MSTEM	2005	Country-wide	Up to 68 MW; 220–300 GWh annually
Biomass (bagasse)	Gibson Energy Ltd.	2004	Country-wide	85–95 MW; over 266 GWh annually
Biomass (wood, sugar cane, coconut)	United Nations	2006	Country-wide	192 MW
Waste-to-energy (sewage)	Scientific Research Council	Cited in 2005 report	Kingston	860–6,300 MWh annually

Recent and Ongoing Assessments of Jamaica's Renewable Energy Potential

Resource	Organization Conducting/ Funding Assessment	Location	Date of Completion
Solar	Wigton Windfarm	Portmore; feasibility assessment for 1 MW grid-connected solar facility	2012
Solar	Solamon Energy	Former bauxite pit mines	N/A*
Wind	Petroleum Corporation of Jamaica/ Renewable Energy and Energy Efficiency Department; JPS; University of the West Indies; University of Technology, Jamaica	Sites suitable for 15 MW or larger wind farms	2009–2014
Wind	Wigton Windfarm, funded by Inter-American Development Bank	20 sites country-wide	2013
Offshore wind	JPS	Harbour View, St. Andrew	N/A
Small hydro	JPS	Great River	N/A
Small hydro	Water Resources Authority	100 sites country-wide	Ongoing measurements of daily stream flow
Biomass (sugarcane bagasse)	Landell Mills Development Consultants Ltd.	Country-wide	2011
Solar, wind, hydro	World Bank Energy Security & Efficiency Enhancement Project	Country-wise	2015

* N/A refers to assessment completion dates that have not yet been announced.

Appendix III. 3TIER Solar Assessment Methodology

To assess an area's solar energy potential, Worldwatch relies on satellite data as well as on data generated from proprietary models of solar irradiance. The mapping company 3TIER, for example, bases its datasets on 15-plus years of hourly, high-resolution (at least 3-kilometer) satellite imagery. 3TIER processes the imagery to create hourly values for irradiance, wind speed, and temperature, allowing the company to generate annual and monthly means and to track variations in daily patterns throughout the year.

3TIER's datasets provide three key measurements of solar energy that together provide the information necessary for developing solar PV and solar thermal projects: global horizontal irradiance (GHI), direct normal irradiance (DNI), and diffuse horizontal irradiance (DIF). (See Table.) Using these data on monthly and daily variations, it is then possible to determine energy generation potentials. The analysis compares monthly variation in solar generation potential to overall electricity demand throughout the year, and the daily variation for each month against the hours of peak demand in the study area. The solar assessment also measures hourly temperatures and wind speeds, as these factors affect generation from PV systems, most of which experience significant power degradation when the unit's temperature rises.[i]

Key Measurements of Irradiation and Their Application to Solar Resource Analysis

Measurement	Description	Application
GHI	Total solar radiation per unit area that is intercepted by a flat, horizontal surface	Of particular interest to PV installations, as it includes both direct beam radiation (radiation directly from the sun) and diffuse radiation (radiation scattered from all directions).
DNI	Total direct beam solar radiation per unit area that is intercepted by a flat surface that is at all times pointed in the direction of the sun	Of particular interest to concentrating solar power installations and installations that track the position of the sun.
DIF	Diffuse solar radiation per unit area that is intercepted by a flat, horizontal surface that is not subject to any shade or shadow and does not arrive on a direct path from the sun	Of particular interest to some PV installations which are best suited to diffuse radiation. DIF is included in the GHI calculation.

3TIER's solar analysis is intended to be used for planning Jamaica's central transmission and generation mix, as well as to provide a window into the aggregate potential of the studied regions and the effects of geographic dispersion on fluctuations in generation. It is too coarse to capture the small area phenomena that can cause dramatic wind acceleration or slowdown and therefore deviations from estimated generation. These issues would be examined in the logical next step of site-specific evaluation. It is at this stage that observational data and further modeling could be used in solar calculations to obtain a more accurate understanding of a site's potential.

Appendix IV. Effects of Wind and Temperature on Solar Potential

For solar PV systems, there is significant power degradation when the module temperature rises. For each degree that the module temperature rises above standard test conditions (STC), the module loses roughly 0.5% of its capacity, by rule of thumb. The conversion from STC (a module temperature of 25 degrees Celsius) to Photovoltaics for Utility Scale Applications (PVUSA) test conditions (PTC) (20°C ambient temperature; module temperature is usually 20–30°C above ambient) and 1 meter per second wind speed results in an 11% de-rating.

Six of the seven sites analyzed by 3TIER for solar power potential in Jamaica experience similar average temperatures, between 25.3°C and 27.0°C, with Wigton significantly cooler with an average annual temperature of 21.9°C. (See Table.) Therefore, efficiency losses resulting from panel warming are fairly uniform across all study sites.

With increased wind speed comes increased heat loss in the module due to convection, and therefore somewhat lower power degradation. Three of the seven sites experience relatively consistent winds above 4 meters per second, helping to make the modules more efficient. Wigton experiences the least loss in efficiency due to cooler temperatures and higher winds.

Wind and Temperature Effects on Solar Generation Potential at Jamaica Zones

Site	GHI (W/m^2 * day)	DNI (W/m^2 * day)	DIF (W/m^2 * day)	Wind Speed (m/s)	Temperature (°C)	Gross Annual Yield (kWh per m^2)
St. Ann's Bay Hospital	216.9	184.3	86.9	4.10	26.2	361.5
Montego Bay Convention Centre	222.7	195.1	85.3	4.90	27.0	372.8
PCJ Building	218.9	188.4	88.0	2.80	26.1	363.4
Soapberry Wastewater Treatment Plant	229.4	207.8	83.3	2.40	26.6	379.0
Scientific Research Council Building	214.0	179.7	90.2	1.80	25.3	353.6
Trade Winds Citrus project	208.9	169.0	90.8	1.90	25.3	340.8
Wigton Windfarm	223.2	193.9	88.4	7.90	21.9	388.3

Appendix V. 3TIER Wind Assessment Methodology

As with solar, Worldwatch relies on data generated from proprietary models to develop our wind resource assessments. The mapping company 3TIER, for example, generates wind resource assessments by means of 25 years of simulated data (January 1987– March 2012) from a mesoscale numerical weather prediction (NWP) model of the atmosphere. Two different model runs are used to create the dataset. First, a 25-year run on a 4,500 meter resolution is done to model long-term variability; this is followed by a one-year run done at a 2,000 meter resolution where the year of each calendar day is chosen sequentially from 2001–2010.

A second dataset is then downscaled to a 200-meter resolution using 3TIER's proprietary Time Varying Microscale (TVM) model. The NWP model represents the roughness of the underlying terrain or water, heat and moisture fluxes into the atmosphere, stability and turbulence within the boundary layer, and wind shear. The coarser grid is used to highlight the effect of general weather patterns on the site, as well as to model regional and thermally driven circulations. The finer grids are used to model the impact of local terrain and local-scale atmospheric circulations on the sites.

Under ideal conditions, each 4.5 by 4.5 kilometer grid point in the 3TIER analysis could hold 40 wind turbines in four rows of 10. Practical considerations such as difficult terrain, aesthetic design considerations, and wake losses (due to interrupted wind flow for wind turbines downstream of other turbines on the same wind farm), however, often make such turbine density unrealistic. It is therefore common to use a Project Layout Discount Factor (PLDF) to account for limitations. Experience shows that the typical spacing for a wind farm might allow for approximately 20 turbines in a 4.5 by 4.5 kilometer area (equaling a PLDF of 50%).

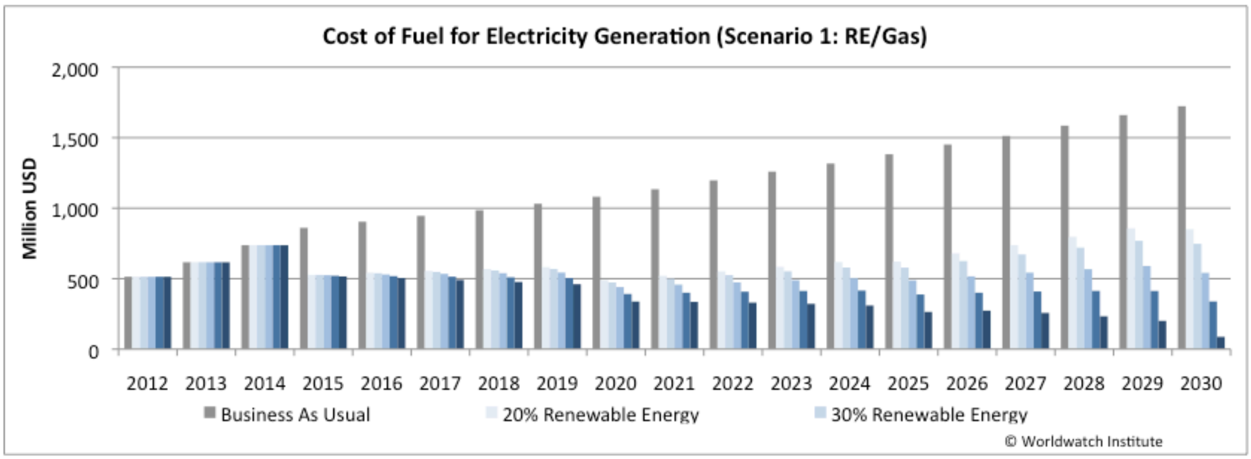
3TIER's calculations of wind power potential assume the use of a 3 MW Vestas V112 turbine (a common model) that is operated at the highest efficiency point, using an "effective wind speed" derived from wind speed, temperature, and pressure data modeled at 10-minute intervals. The result is a capacity factor estimate for each grid point, which measures the amount of power potentially generated compared with the installed capacity of the generation plant. For example, if a 3 MW turbine generated 1 MW of electricity on average, the capacity factor would be one-third, or 33%.

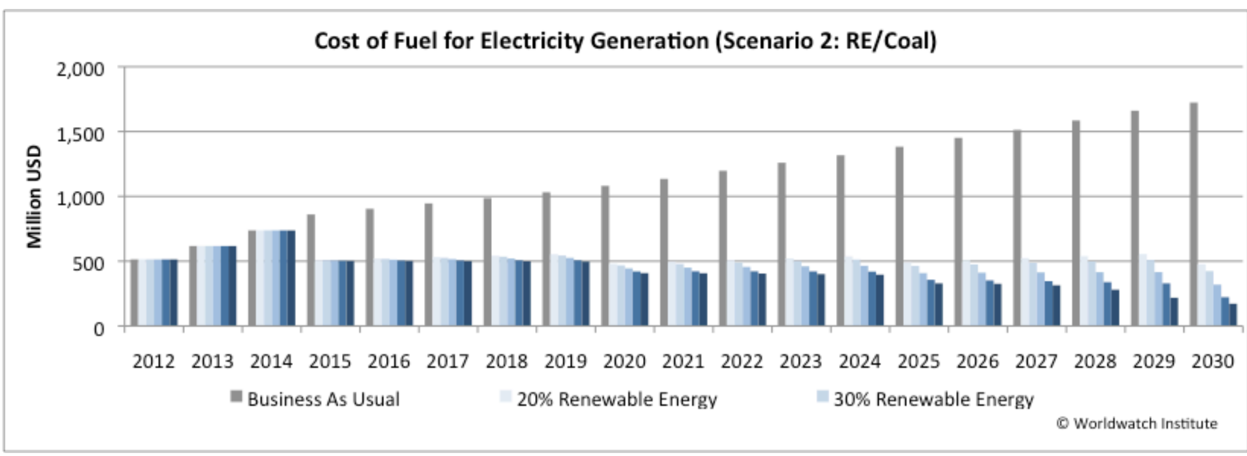
For high-resolution wind resource assessments that are site specific, 3TIER identifies grid points in each zone that have capacity factors of more than 20%, 25%, and 30%, respectively, to determine the areas with the greatest potential. A grid point with a PLDF of 50% would produce 52.5 gigawatt-hours per year (GWh/yr) at a 20% capacity factor, 65.7 GWh/yr at 25%, and 158 GWh/yr at 30%, using the 3 MW V90 turbines.

3TIER performed a granular analysis for three zones: Portland parish, Retrieve, and offshore wind. The data presented in Chapter 3 represent mean data for several points assessed in each zone. These points were not chosen to represent actual wind farms, but instead to best characterize the entire wind zone.

Appendix VI. Fuel Costs for Alternative Energy Scenarios

Using renewable energy resource data, projected electricity generation costs, and power demand projections, Worldwatch developed three scenario groups for Jamaica's transition to renewable energy through 2030 based on current petroleum capacity, or installation of new natural gas or coal power plants. Fuel costs through 2030 for the petroleum-based energy scenarios are presented in Chapter 6. This appendix presents fuel costs for the natural gas- and coal-based scenarios (see Figures below).





Appendix VII. Renewable Procurement Processes Prior to November 2012

OUR used the avoided cost of electricity generation to set the price that JPS, the transmission and distribution monopoly, would pay independent power producers (IPPs) for their electricity for capacity up to 25 MW. OUR claims to calculate avoided cost based on a "fair allocation of cost" between JPS and IPPs, so the avoided cost includes the transmission and distribution costs borne by JPS in addition to generation costs.[ii]

Typically, "avoided cost" refers to the most expensive existing generation that is offset by building new electricity capacity. When a new facility adds new power to the electricity grid system, the grid operator will typically reduce the amount of electricity generated or purchased from the system's most expensive existing power plant to achieve the greatest cost savings for the utility. The cost per kWh of electricity generation from this most expensive plant is known as the "avoided cost," since it is the cost that the utility "avoids" paying when electricity generated from a new power source enables it to reduce the output from that existing plant.

OUR, however, uses the term "avoided cost" to refer to future capacity additions that will no longer be needed due to the new capacity. The generation costs of these future plants are based on the country's Least Cost Expansion Plan for the electricity sector, "Guidelines for Addition of New Generating Capacity to Public Electricity Supply Systems," and fuel cost projection. The OUR avoided cost is set equal to the Long Range Marginal Cost (LRMC)—the cost of producing each additional kWh of electricity—of the last additional generation in the LCEP that will not be added to the electricity grid system due to the new power capacity.

The OUR calculation results in unrealistically low avoided cost levels based on assumptions that large amounts of natural gas generation capacity will come onto the grid in the next few years, with low cost assumptions for the price of natural gas imports. In contrast, avoided cost based on existing plants in Jamaica would likely come from diesel generators, since these have some of the highest operating costs in the country.

Several assumptions in the OUR calculations also result in a lower level of avoided cost, including the assumption that fuel costs will remain constant over time. OUR also assumes higher efficiencies and lower operation and maintenance costs than are currently observed in Jamaica.

In 2010, OUR set the level of avoided cost in Jamaica at 9.33 U.S. cents per kWh. OUR claimed to promote renewable sources such as wind and solar by allowing them up to a 15% price premium over the avoided cost level—meaning that JPS purchases power from renewable electricity generators at up to 10.73 cents per kWh.

MSTEM Minister Paulwell summed up the "unfortunate situation" under the avoided cost regime that renewable generators are "being asked to sell electricity at around USD 0.11 per kWh when Jamaica's current cost of generating electricity from oil is around USD 0.25 per kWh."

Not all renewable energy generation projects were subject to the avoided cost price. OUR classifies renewable energy projects in Jamaica according to three size categories for determining an off-take price:

1. Less than 100 kW: Typically a self-generating consumer who will be taking advantage of the recently implemented net billing provision.

2. 100 kW to 25 MW: IPPs that are assigned the avoided cost plus a 0–15% premium. Currently, this classification applies only to wind projects, as no solar projects of this size exist and because JPS owns all of Jamaica's hydropower generation. OUR determines the premium level based on factors such as project cost structure and displacement of fossil fuels.

3. Above 25 MW: These projects have to be put out for public tender, and the off-take price is negotiated individually taking into consideration a demand forecast, future impact on system load, and overall generation.

Despite these guidelines, current cost-setting procedures have often varied by individual project, as determined by the terms of each power purchase agreement (PPA). The processes for settling on PPAs are also relatively opaque. The case of Wigton Windfarm illustrates clearly the difficulties of operating a profitable renewable IPP in Jamaica. Under the price set in the original PPA with JPS, Wigton was unable to turn a profit through its electricity sales. Only after a recent renegotiation has Wigton received electricity prices sufficient to finance its operations sustainably.

Appendix VIII. Selected Private Financial Institution Loan Package Terms for Businesses in Jamaica

Name of Institution	Type of Institution	Loan Size	Interest Rates Available	Loan Repayment Timeframe	Relevant Types of Projects Supported
Scotiabank Jamaica*	Commercial bank	N/A**	N/A	N/A	Power generation and transmission
CIBC FirstCaribbean International Bank*	Commercial bank	N/A	Tied to market rates (average lending rate was 17.46% in June 2012)	Maximum five years, unless in exceptional circumstances	N/A
Citi Jamaica	Commercial bank	N/A	N/A	N/A	N/A
National Commercial Bank Jamaica*	Commercial bank	Up to USD 250,000	N/A	Eight years; six-month moratorium on principal payments	N/A
First Global Bank*	Commercial bank	N/A	N/A	N/A	Go Green Energy Saver Loan for businesses or residences, including for solar water heating, PV, bio-digesters, wind turbines
RBC Royal Bank (RBTT Jamaica)*	Commercial bank	USD 50,000–250,000	N/A	5–7 years	N/A
PanCaribbean Bank*	Commercial bank	N/A	N/A	N/A	N/A
Capital & Credit Merchant Bank*	Merchant bank	N/A	Maximum 13%	Up to 10 years	Energy, especially alternative and renewable
MF&G Trust & Finance	Merchant bank	N/A	N/A	Maximum five years	N/A
Jamaica Cooperative Credit Union League*	N/A	N/A	N/A	N/A	N/A
Jamaica Money Market Brokers*	N/A	N/A	N/A	N/A	N/A
Jamaica National Building Society*	Building society	Approx. USD 700–4,700***	Weekly rate of 1%	N/A	Small business loans
National ExIm Bank Jamaica*	Export-import bank	Up to USD 500,000	10–11.5%	Maximum four years, including possible six-month moratorium on principal	Small and medium-sized enterprise (SME) loans
National People's Cooperative Bank*	Cooperative bank (including DBJ-funded loans)	Up to USD 235,000***	9.5–11%	N/A	Energy conservation/cost reduction, SME; 70–80% of project cost

* These banks are considered Approved Financial Institutions (AFIs) by the Development Bank of Jamaica.
** N/A indicates that data are not available.
*** Based on an exchange rate of J$85 = USD 1.

Source: See Endnote iii for this section.

Appendix IX. Internationally Funded Energy Efficiency and Renewable Energy Projects

Funder	Program	Dates	Key Aspects	Success
United Nations Development Programme (UNDP)	Energy sector capacity building	Ongoing through 2014	• Build public sector capacity for reducing government energy consumption; energy efficiency manual and training sessions for public employees (in Kingston, Montego Bay, and Mandeville) • Technical assistance for small-scale wind energy, including data collection and feasibility studies for wind sites • Public-private dialogue platform to establish links between government and energy stakeholders (total budget of USD 272,000, with USD 100,000 from UNDP; currently seeking funding partners)	Project ongoing
Inter-American Development Bank (IDB)	Caribbean Electric Utility Services Corporation (CARILEC) Energy Efficiency and Renewable Energy Project	Ongoing	• Reduced price trainings for Certified Energy Managers as part of the capacity building component of the project	Project ongoing
Austrian Development Cooperation, Latin American Energy Organ-ization–OLADE	Strengthen institutional framework for energy efficiency in the region	Ongoing	• Guidance of national programs, including laws and regulations	Project ongoing
United Nations	Sustainable Energy for All	Launched July 31, 2012 through 2030	• Ensure universal access to modern energy services • Double the global rate of improvement in energy efficiency • Double the share of renewable energy in the global energy mix	Project ongoing
IDB	Energy Efficiency and Conservation Programme, Phase I	Four-year period, launched in May 2012	Total loan of USD 20 million, incl.: • USD 17 million for hardware (solar lighting, CFLs, LED, sealing and insulation, solar water heating high-efficiency AC) • USD 1.7 million for institutional strengthening • USD 1 million for demand-side management and energy efficiency best practice education	• Expected electricity consumption decrease of 22,609 MWh per year • Expected annual electricity savings of USD 9 million
European Union	Jamaica Productivity Center ESCo Project	36 months starting in 2012	• USD 65 million • ESCo training workshops, audits, and public awareness for energy conservation	• Public sector energy savings • Increased energy conservation investment in private sector, incl. small and medium-sized enterprises (SMEs)
World Bank	Energy	August	• Total cost USD 15 million,	• Expected reduction in

	Security and Efficiency Enhancement	2011–December 2015	including USD 5 million to DBJ for Energy Line of Credit and USD 10 million to MSTEM for workshops, studies, and public awareness efforts • Technical, cost, and feasibility studies for energy efficiency, LNG, and renewables projects • Grid assessment under way to determine technical and regulatory challenges for adding renewable capacity	generation costs from USD 21 to USD 12/MWh • Expected construction/ installation of 520 MW of new generating capacity • Expected new energy sector regulations approved • Expected increase in appliance labeling • Expected USD 625 million new investment in electrical sector
Development Bank of Jamaica (DBJ), PetroCaribe, World Bank, IDB	Energy Fund	Ongoing, launched in 2008	• Loans to SMEs for energy efficiency and conservation and alternative energy production • Disbursed through private banks, credit unions, and microfinance institutions	• Only 14% of funds were lent in first two years • Lack of internal capacity on the part of banks and energy developers to use funds effectively
Cuba	CFL distribution	2006	• Distribution of 4 million CFLs donated by Cuba to Jamaican households	• Reduced Jamaica's electric load by 80 MW • Reduced demand by 48,500 MWh per year • Widespread public acceptance of CFLs
UNDP, IDB	PCJ EEU Programme of Environmental Management in Hospitals and Schools	2006	• UNDP and Jamaican government jointly funded energy audits • IDB and Jamaican government jointly funded implementation of audit recommendations through loans and grants	• Inconsistent follow-up and implementation of audit recommendations • UNDP helped with solar system installation in four hospitals previously audited by government
U.S. Agency for International Development – Energy Audits for Sustainable Tourism	PCJ EEU Certified Energy Manager training	2005	• Energy efficiency training	Data not available
World Bank	JPS Solar Water Heating (SWH) initiative	1998–2001	• Installed 300 residential solar water heating systems with 200–300 liter capacities • Installed SWH at 10 hotels and two student residences • Tax reductions and exemptions for SWH equipment	• Payback in 4–5 years • Average savings of 1,825 kWh/household/yr. • Helped establish Jamaica's SWH market; over 1,000 systems installed in 2000
World Bank Global Environment Facility (GEF), IDB, Rockefeller Foundation, Canadian Trust Facility	JPS Demand-Side Management program	1994–1999	• Residential Phase 1 provided 100 households with CFLs, refrigerator door gaskets, and other efficiency technologies • Residential Phase 2 sold 100,000 CFLs and other equipment at discounted prices with 12-month financing option • Fast-track connection for renewable and cogeneration facilities under 2 MW • Commercial energy audits, including lighting and AC recommendations • Commercial and residential SWH • Pilot testing of rural residential	Data not available

			solar PV • Awareness campaign	

Source: See Endnote iv for this section.

Appendix X. International Financing Institutions

In addition to the development finance institutions mentioned in the Roadmap text, there are several other sources of traditional development assistance that could be tapped for sustainable energy project finance. These are listed in the table below.

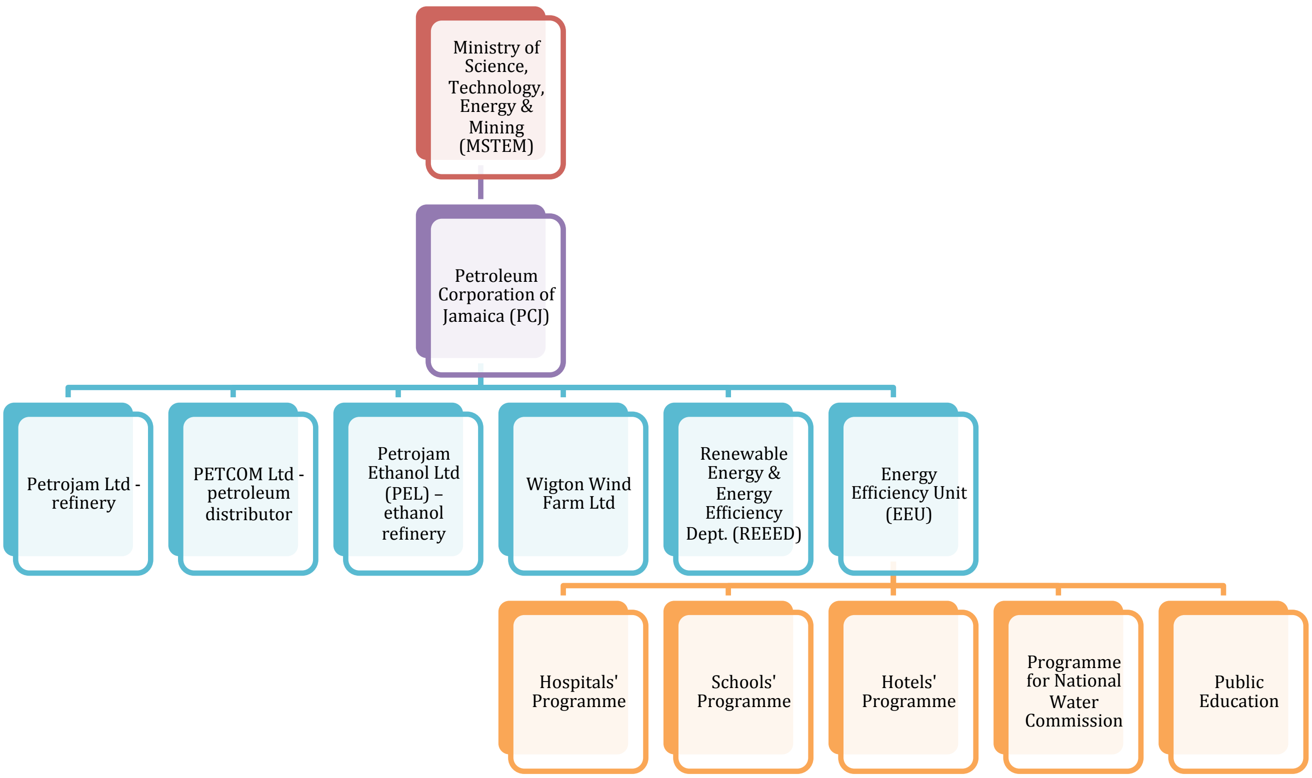
Institution	Overview	Sustainable Energy Portfolio	Preferred Project Types	Relevant International Projects	Work in Jamaica/ Latin America and Caribbean (LAC) Region
World Bank – International Bank for Reconstruction and Development (IBRD)	Lends to governments of middle-income and creditworthy low-income countries; promotes sustainable development through loans, guarantees, risk management products, and advisory services	USD 1.3 billion of IBRD new renewable energy (RE) and energy efficiency (EE) financing in 2009, double the level in 2008	Capacity-building for local banks to invest in RE/EE; access extension, transmission and distribution improvement, efficiency	Electrification of 1,700 households in Ecuador from solar home systems (2008); electrical grid extension for more than 100,000 people in Peru (2009)	USD 7 billion climate change portfolio for LAC; 2005–08 project on "secure and clean energy" helped cut DR electricity losses by 14%.
World Bank – International Finance Corporation (IFC)	Provides investment services, advisory services, and asset management to clients in more than 100 developing countries.	Financed more than USD 2.3 billion in RE projects since 2005; committed to providing a further USD 3 billion for RE/EE projects for 2009–11	Renewables are 70% of total investment in energy sector; support of biomass, geothermal, hydro, solar, and wind; hydro is largest component of portfolio	USD 50 million for a 72 MW geothermal project in Nicaragua, by U.S.-based Ram Power Corp; USD 50 million over 20 years for 2.7 MW waste-to-energy in the Maldives	USD 3 billion to LAC region in 2010
Global Environment Facility (GEF)	Independently operating financial organization; largest public funder of environment-related projects	USD 1.14 billion from 1991 to 2009, plus USD 8.3 billion in co-financing; since 2009, decreasing share of RE due to greater emphasis on EE, maturation of previous projects, and suspension of off-grid activities.	Market-based solutions to promote renewable electricity in grid-based systems; sustainable biomass and small hydro have large share; maturing renewable technologies and off-grid not a priority	Technical capacity-building in Cuba for biomass and wind generation (2011); creating market conditions conducive to small/medium renewable generation in Cape Verde (2012)	LAC region 21% of total funding; USD 1.3 million grant for biomass generation in the DR (2012)
European Investment Bank (EIB)	EU Bank aims to makes long-term finance available for sound investment	USD 5.4 billion in 2010, up from USD 1.1 billion in 2007; non-EU funding channeled through Energy Sustainability and Security of Supply Facility (ESF)	Preference for wind and solar generation; encourages new technologies like off-shore wind, next-generation biofuels, and solar PV	EUR 45 million for 28 MW onshore wind farm in Cape Verde; financing 117 MW hydropower plant in Panama	EUR 800 million for African, Caribbean and Pacific (ACP) countries and South Africa in 2011; EUR 100 million over past five years in DR—25% for energy

EU Directorate-General for Development (EUROPEAID)	Responsible for designing EU development policy and delivering aid; promotes poverty reduction, sustainable development, democracy, and security	EUR 420 million from 2006–13 through the ACP-EU Energy Facility; EUR 150 million in grants under the 10th European Development Fund (EDF), 2008–13, for countries prioritizing energy	Officially endorsed Sustainable Energy for All initiative; assistance for implementing incentives, PPAs, FITs; solar (including PV), wind, small hydro, and biomass for electricity generation	EUR 4 million for 2008–11 project in Uganda to develop solar, hydro, and efficient household stoves; 25% financing of EUR 340 million, 200 MW wind farm in Egypt, partnered with KfW (see below)	EUR 194 million for DR under 10th EDF, but for focal areas governance, poverty, health and education (about 50% of allocation); environmental sustainability and energy are considered for funding in the region
Global Energy Efficiency and Renewable Energy Fund (GEEREF)	Provides global risk capital through private investment for EE and RE projects in developing countries	Target funding size of EUR 200–250 million; as of September 2009, GEEREF had secured a total EUR 108 million	Provides indirect equity finance to small and medium-sized enterprises (SMEs); projects are RE or EE that require up to EUR 10 million investment and fill a gap in the market	Investments have been made in RE Asia Fund Berkeley, Clean Tech Latin American Fund, DI Frontier (RE projects and carbon trading in Africa)	Priority focus on ACP; no existing projects in the LAC region
Nordic Investment Bank (NIB)	International financial institution owned by Denmark, Estonia, Finland, Iceland, Latvia, Lithuania, Norway, and Sweden; projects to strengthen competitiveness and/or enhance the environment	USD 113 million in 2010 for investment in international green energy project, a notable reduction since 2008 (USD 378 million).	Upgrading electricity transmission and distribution systems; renewable energy power projects	On-lending for energy projects with environmental benefits in southern Africa (2011); loan to Inter-American Investment Corporation for projects within NIB's mandate (2011)	LAC region could be among "limited group" of countries where NIB sees good opportunity to maintain a long-term presence
Inter-American Development Bank (IDB)	Of the IDB's 48 member countries, 26 LAC countries hold the majority of shares; aims to bring about development in a sustainable, climate-friendly way.	USD 83 million in 2010, a sharp decrease from 2008 (USD 662 million).	Hydro, biofuels, wind, solar, and geothermal power; emphasis on energy efficiency	Ongoing electricity losses project in Guyana (monitoring, technical and commercial losses); pledged USD 600 million in March 2012 for green energy in LAC	USD 1.5–1.9 billion planned for 2009–13 in the DR, with long-term infrastructure objectives
Caribbean Development Bank (CDB)	Aims to reduce poverty through sustainable economic and social development	Virtually non-existent so far (few million dollars for regional expertise-building in 2011); progressively making RE/EE a top priority	Energy efficiency, conservation, and diversification; regional initiatives to create the appropriate RE/EE policy	Promotion of regional building code; involved in construction of 30 MW bagasse project in Belize (2008); biomass project at the Skeldon factory in Guyana	Data not available

			environment		
Agence Française de Développement (AFD)	Main implementing agency for France's official development assistance to developing countries and overseas territories; also possesses private sector-oriented subsidiary, PROPARCO	USD 294 million in 2010, stable since 2007	Connection/ strengthening electricity grids; holistic electrification approach—both grid and off-grid projects; both EE and RE projects	Rural electrification program in Morocco (1995–2010) through grid extension and off-grid solar PV; creation of a regulatory body for regional electricity exchange in West Africa	Recent funding in Latin America, long-standing in Haiti and DR; EUR 400 million in projects since 1997, growing involvement
Kreditanstalt für Wiederaufbau (KfW) and affiliated DEG	KfW partners with DEG to promote sustainable progress in developing countries; KfW emphasis on partner countries, DEG emphasis on the private sector	USD 1.5 billion in 2010, nearly doubled since 2007; increasing reliance on private funds rather than German government funding	Protecting tropical forests, biodiversity, and natural resources (KfW); climate protection investments of private firms (DEG)	EUR 5.5 million German-funded "Promaren" program to protect natural resources in the DR (KfW); long-term loan to India-based Bhoruka Power Corp. for 26 MW wind farm (DEG)	DEG in particular has invested about USD 84 million in LAC infrastructure projects over 20 years
International Climate Initiative (ICI)	Funded by emissions trading, the German Environment Ministry (BMU); finances climate and biodiversity projects in developing and newly industrializing countries	EUR 634 million funding since 2008, plus EUR 1.5 billion in co-financing; 28% of projects go to RE and EE	Actor in International Partnership on Mitigation and monitoring, reporting, and verification (MRV); investment and policy advice to encourage RE and EE; strategies for managing risks due to climate change	Improving know-how for application of RE technologies in South Africa (2008–10); switching from fossil fuels to biofuels on the Galapagos Islands (2012–14)	Worldwatch Low-Carbon Energy Roadmaps to promote EE and RE in the Caribbean—EUR 1.3 million funding over 2011–13

Source: See Endnote v for this section.

Appendix XI. Electricity Governance Structure in Jamaica



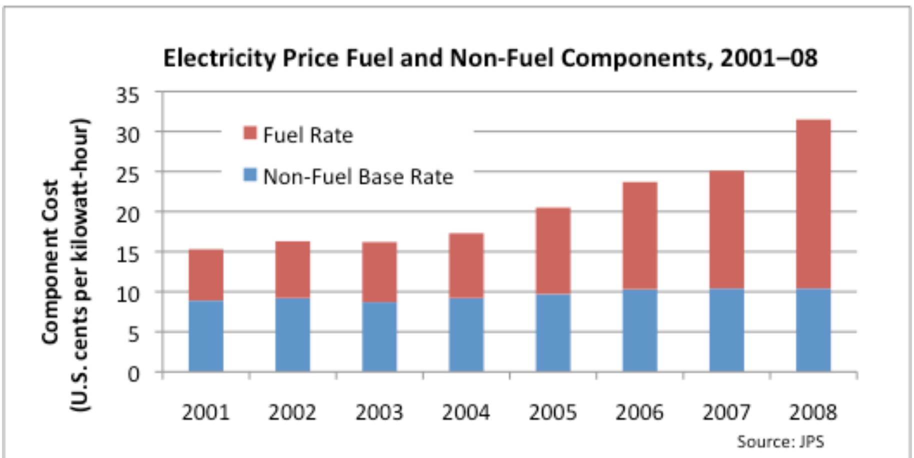
© Worldwatch Institute. Source: MSTEM

Appendix XII. Electricity Price-Setting in Jamaica

OUR sets the prices that JPS pays to independent power producers (IPPs) for electricity generation from various sources, as well as rates that electricity consumers must pay to JPS for their electricity consumption. As examined in Chapter 1, electricity prices in Jamaica are very high when compared internationally. OUR sets the consumer electricity rate based on two components: the fuel rate and the non-fuel rate.[vi]

The fuel rate depends on the cost of fuel, the heat rate (efficiency) of power plants, and the loss rate on the grid. Lower heat rates (higher efficiencies) in power plants allows them to use less fuel to generate the same amount of electricity, thereby lowering the fuel rate component of the consumer electricity charge. Similarly, lower transmission and distribution grid loss rates mean that for the same amount of electricity delivered to customers, power plants have to generate less power because less is lost on the way to the end user.

Between 2001 and 2008, the fuel rate component of JPS electricity charges increased greatly from 6.4 U.S. cents per kWh to 21.1 U.S. cents per kWh, as grid losses increased from 17% to 22.4%, and oil prices increased from USD 30.38 to USD 99.67 per barrel over the same period.[vii] (See Figure.)



JPS determines its non-fuel costs by calculating its total costs (capital and operating expenses) to set its revenue requirement. In its 2009–2014 Tariff Review Application, JPS estimated its annual costs (and therefore its revenue requirements) at USD 444 million, of which transmission and distribution capital and operating costs accounted for 27.3%.[viii]

JPS then spreads this cost over its different customer categories, through both a monthly charge and a per kWh rate, in order to collect the total revenue. For large electricity consumers, JPS charges an additional fee based on the level of energy demand.[ix] (See Table.)

Although the smallest residential consumers are charged the comparably low non-fuel rate of 7.3 U.S. cents per kWh, most Jamaican households consume more than the maximum 100 kWh per month. These households are charged the high rate of 20.8 U.S. cents per kWh for consumption beyond the 100 kWh per month threshold, the highest non-fuel rate charge for any consumer class.[x]

In June 2012, OUR authorized a non-fuel rate increase of 1.1–1.2%, and a 7.5% increase in the monthly customer charge.[xi] OUR states that the increase in the non-fuel rate base should be offset by increased efficiency requirements, which it estimates will reduce the fuel component tariff by 2.6% for what OUR estimates will be an overall electricity price reduction of about 1.4%.[xii]

In another recent step to exert its regulatory authority to protect consumers, OUR limited the period of time that JPS can back-bill electricity customers—that is, bill for previous periods based on under billing or failure to generate bills due to internal system faults—to two months.[xiii] JPS can still back-bill based on meter tampering and fraud for up to six years.

JPS Proposed Non-Fuel Customer Charge Rates

				Demand Charge (USD per kilovolt-ampere)		
Rate Category	**Customer Consumption (kWh per month) or Time of Use**	**Monthly Customer Charge (USD per month)**	**Energy Charge (USD per kWh)**	**Standard and On-peak Times**	**Partial Peak Times**	**Off-peak Times**
Residential	<100	2.24	0.073	N/A	N/A	N/A
	100–500	5.59	0.208	N/A	N/A	N/A
	>500	5.59	0.208	N/A	N/A	N/A
General service	<100	5.59	0.099	N/A	N/A	N/A
	100–1,000	11.24	0.174	N/A	N/A	N/A
	1,000–3,000	28.06	0.174	N/A	N/A	N/A
	>2,000	56.18	0.174	N/A	N/A	N/A
Power service	Standard	128.89	0.062	17.00	N/A	N/A
	Time of use	128.89	0.062	9.57	8.00	0.72
Large power	Standard	128.89	0.058	16.11	N/A	N/A
	Time of use	128.89	0.058	9.18	7.13	0.50
Streetlight	N/A	106.64	0.199	N/A	N/A	N/A

Note: N/A indicates that data are not available.

Appendix XIII. General Consumption Tax Exemptions and Recommended Import Duty Exemptions

Technologies Exempted from General Consumption Tax (GCT) Under the 2012 GCT Act

- Lighting equipment
  - Compact fluorescent lamps and ballast
  - Fluorescent fixtures and tubes
  - Circular fluorescent lamps
  - Fluorescent ballasts
  - High-intensity discharge fixtures and bulbs
  - Fiber glass panels for skylighting
- Automated, electronic, or computerized lighting control system including occupancy sensors and photo-cells for such systems
- Solar panels and tubes for solar water heating systems
- Solar cells designed to produce electricity from the sun
- Apparatus or machinery designed to produce motive power heat, light, or electricity through the utilization of renewable sources of energy, for example, sun, wind, and water
- Solar driers
- Solar electric fans
- Solar electric refrigerators
- Solar water pumping and accessories
- Solar street and walkway lamps
- Parking area and security solar lighting systems
- Brackets and mount for solar lights
- Bulbs for solar powered systems
- Lighting control units
- Occupancy sensors
- Seven-day and 24-hour timers
- Water-saving equipment
  - Water-saving shower heads
  - Flow restrictors for water faucets
- Power factor correction capacitors
- Ice thermal storage air conditioning systems
- Air conditioning chillers with rotary screw compressors
- Polyurethane foam insulation for roofs
- Reflective films for glass windows
- Photovoltaic panels
- Charge controllers
- Safety disconnects
- Load breakers
- Negative bonding blocks
- Transfer switch
- Inverters
- Photovoltaic batteries
- Wind turbines and support accessories

Import Duty Exemptions Approved by Jamaican Cabinet, Seeking CARICOM Approval

Tariff Code	Description of Item (s)	Current Rate of Duty
8539.31	Compact Fluorescent Lamps	20%
8415.82	Air Conditioning Chillers with Rotary Screw Compressors	20%
8418.29.10 (Electric)	Vapour Absorption Refrigeration Systems	20%
8418.29.20 (Solar Non-Electric)	Vapour Absorption Refrigeration Systems	20%
8415.82	Thermal Storage Air Conditioning Systems	20%
8415.10	Ice Thermal Storage Air Conditioning Systems	20%
8415.20	Air Conditioning Chillers with Rotary Screw Compressors	20%
8414.51	Solar Electric Fans	20%
8418.21.20	Solar Electric Refrigerators	20%
3925.90.90 (Plastic)	Solar Water Heating mounting accessories	15%
8506.80, 8507.80	Photovoltaic Cycle Batteries	20%
8539.39	Bulbs for Solar Powered System	20%
8418.29.10 (Electric)	Absorption Refrigeration Equipment and Materials utilizing solar energy	20%
8418.29.20 (Solar Non-Electric)	Absorption Refrigeration Equipment and Materials utilizing solar energy	20%

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