Sustainable Energy Framework for Barbados
ATN/OC-11473-BA

Final Report—Volume 2 (Appendices)
Government of Barbados
Inter-American Development Bank

June 2010
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Appendix A: Laws and Regulations Governing the Electricity Sector in Barbados

Laws and Regulations that govern the electricity sector in Barbados are:

- The Electricity Act, Chapter 277 of the Laws of Barbados
- The Electric Light and Power Act, Chapter 278 of the Laws of Barbados
- The Fair Trading Commission Act, Chapter 326B of the Laws of Barbados
- The Utilities Regulation Act, Chapter 282 of the Laws of Barbados.

Below we review the key aspects related to energy efficiency and renewable energy of each of these.

A.1 The Electricity Act

The Electricity Act, Chapter 277 of the Laws of Barbados (the ‘Electricity Act’) is described as “an Act to provide for the inspection and control of electrical works and for other purposes in connection therewith”. It is an Act that defines what is meant by the term “electricity” and “electrical equipment”, and defines the latter as all wires, conductors and all apparatus connected to these items for the purpose of conveying, transmitting or distributing electricity for any purpose. The Act enshrines the position of “Electrical Engineer” in the government administration, and is primarily concerned with safety.

The Act provides that no alterations or extensions to any installation should take place without the permission of the Electrical Engineer. The Act provides for the Electrical Engineer to enter any premises at reasonable times to inspect any electrical fittings or apparatus to satisfy themselves that the provisions of this Act or the provisions of the Wireless Telegraphy Act, and the related regulations have been observed.

The Act has provisions for appeal, and where an applicant for the supply of electricity is dissatisfied with the decision of the Electrical Engineer, they may appeal to the Minister who shall enquire into and decide upon the matter, and the decision of the Minister shall be final.

A.2 The Fair Trading Commission Act

The Fair Trading Commission Act (FTC Act) provides for the establishment of a Fair Trading Commission (“the Commission”) to safeguard the interests of consumers, regulate utility services supplied by service providers, monitor and investigate the conduct of service providers and business enterprises, and promote and maintain effective competition in the economy of Barbados.

In addition to administering The Fair Trading Commission Act itself, the FTC Act also provides for the FTC to administer other laws under its purview which are:

- The Utilities Regulation Act, Chapter 282 of the Laws of Barbados and Utility Regulation Act Procedural Rules
- The Telecommunications Act, Chapter 282B of the Laws of Barbados
- The Fair Competition Act Chapter 326D of the Laws of Barbados.
The Commission is a body corporate and subject to Section 21 of the Interpretation Act. The Commission is required to carry out its functions in a manner that will promote efficiency and encourage competition among service providers and business enterprises, and improve the standards of service and quality of goods and services in Barbados.

The functions of the Commission, as set out in Section 4. (1), are to “enforce the Utilities Regulation Act and any laws relating to consumer protection and fair competition which the Commission has jurisdiction to administer”.

Specifically, in relation to the regulation of public utilities, the Act requires the Commission to:

- Establish principles for arriving at the rates to be charged by service providers
- Set and monitor the maximum rates to be charged by service providers
- Determine and monitor the standards of service applicable to service providers
- Carry out periodic reviews of the rates and the principles by which they are set, as well as the standards of service supplied by service providers
- Hear and determine complaints by consumers regarding billings and the standards of service supplied by service providers.

The Act also requires the Commission to:

- Keep commercial activities under review
- Receive and evaluate consumer complaints
- Educate and assist consumers in resolving complaints
- Investigate whether business enterprises are engaging in anti-competitive business practices.

The Commission may, on its own initiative, or upon the request of any person, carry out any investigation that it considers necessary or desirable in connection with matters under the purview of the FTC Act.

The FTC Act provides at Section 17 that “the Minister may, after consultation with the Chairman, give the Commission directions of a general nature in respect of the policy to be followed by the Commission in exercising its functions in respect of utility regulation, consumer protection matters and fair competition matters, and the Commission shall comply with those directions.”

Annual expenses of the Commission are financed by, *inter alia*, amounts voted from Parliament and sums levied on the service providers. However, it is also provided that the maximum amount levied on a service provider should not exceed one percent of that service provider’s gross sales.

**A.3 The Electric Light and Power Act**

The Electric Light and Power Act (ELPA), Chapter 278 of the laws of Barbados, is the principal Act that regulates the supply of electricity in Barbados. It is “an Act to facilitate and regulate the supply and use of electricity for Lighting and other purposes, and to confirm certain provisional orders made under the Electric Light and Power Act, 1899”.
The Act provides that no local authority, company or person shall supply electricity in any area except under an Act or under a provisional order granted under the ELPA. However, it states that this provision “shall not prevent any company or person from affording a supply of electrical energy to any other company or person where the business of the company or person affording the supply is not primarily that of the supply of electrical energy to consumers”. Further, the Act allows for the Minister, by provisional order, to grant to any local authority, company or person an exclusive right to supply electricity for any public or private purposes within any area, and for such period as the Minister may think proper, but subject to the provisions of section (2) of the Act, a provisional order for any period, up to forty-two years from the commencement of the order granting such rights.

The Minister may from time to time “make, rescind, alter or vary rules, including forms, in relation to applications for provisional orders and to the payments to be made in respect thereof and to the publication of notices and advertisements and to the manner in which, and the time within which representations or objections with reference to any application are to be made and to the holding of local enquiries in such cases as he may think advisable and to any other matters arising under this Act.” The Act also provides that electricity providers shall be subject to such regulations and conditions as may be inserted in any order or special Act with regard to the following matters:

1. the limits within which and the conditions under which a supply of electricity is to be provided
2. the securing of a regular and efficient supply of electricity
3. securing the safety of the public from personal injury or from fire or otherwise
4. the limitation of the prices to be charged in respect of the supply of electricity
5. the authorizing of inspection and enquiry from time to time by the Minister and the local authority
6. the enforcement of the performance of the duties of the undertakers in relation to the supply of electricity by the imposition of penalties or otherwise and the revocation of the order or special Act, where the undertakers have, in the opinion of the Minister, practically failed to carry the powers granted to them into effect within a reasonable time or discontinued the exercise of such powers
7. for any other matter related to any electricity undertaking, the Minister may, with the approval of Parliament from time to time, make such regulations as he may think expedient for securing the safety of the public from personal injury or from fire or otherwise and may from time to time amend or repeal any regulations which may be contained in any order or special Act in relation thereto.

The provision of the ELPA, mentioned above, by which electricity providers shall be subject to a limitation of prices empowers the Minister in charge of energy to place limits on the prices to be charged for the supply of electricity. This provision seems in conflict with the provisions of Section 4.(3) (b) of the Fair Trading Act, which empowers the FTC to regulate the prices charged by electric utilities.
A.4 The Utilities Regulation Act

The Utilities Regulation Act (URA) is administered by the Fair Trading Commission, which is established under Section 3 of the Fair Trading Commission Act, Chapter 326B of the Laws of Barbados.

The URA details that functions of the Commission are, in relation to service providers, to:

- establish principles for arriving at the rates to be charged
- set the maximum rates to be charged
- monitor the rates charged to ensure compliance
- determine the standards of service applicable
- monitor the standards of service supplied to ensure compliance
- carry out periodic reviews of the rates and principles for setting rates and standards of service.

The URA directs the FTC as to what factors should be considered by the FTC in establishing the principles referred to above. In that regard, the FTC is required to consider:

- the promotion of efficiency on the part of service providers
- that an efficient service provider be able to finance its functions by earning a reasonable return on capital
- such other matters as the Commission may consider appropriate.

The URA further directs the FTC to protect the interests of consumers by ensuring that service providers supply “service that is safe, adequate, efficient and reasonable”, and that the FTC “shall hear and determine complaints by consumers regarding billings and the standards of service supplied”.

In determining standards of service, the Commission the FTC is also required to consider:

- the rates being charged by the service provider for supplying a utility service;
- ensuring that consumers are provided with universal access to the services supplied by the service provider
- the national environmental policy.

Section 7 of the FTC Act provides for the appointment of a Director of Utility Regulation who shall be the chief technical officer in respect of utility regulation and shall perform the functions assigned by the Chief Executive Officer appointed under Section 6 of the FTC Act.

A panel of Commissioners referred to in Section 5 of the FTC Act is required to sit to hear and determine complaints by consumers regarding billings and standards of service supplied by service providers, and applications made by service providers for increases in rates. A decision of the panel is as valid and binding as if it had been made by the Commission.
Appendix B: Key Entities in Barbados with Responsibility in the Energy Sector

The Government and the private sector are involved in the supply and distribution of energy in Barbados. Electricity production, transmission and distribution are handled entirely by BL&P, a private firm, and there is a mix of state-owned-enterprises and private companies involved in petroleum production, supply and distribution. The key entities involved in the sector are:

- The Ministry of Finance, Investment, Telecommunications, and Energy (MFIE)
- The Fair Trading Commission (FTC)
- The Barbados Light & Power Company Limited (BL&P)
- The Barbados National Oil Company Limited (BNOCL)
- The National Petroleum Corporation (NPC)
- The Barbados National Terminal Company Limited (BNTCL).

The MFIE and the FTC are responsible for the regulation of the energy sector and the development of policy. Other entities listed are responsible for the delivery of energy supplies and services. Individual roles of these institutions are discussed in the following sections.

B.1 The Ministry of Finance, Investment, Telecommunications, and Energy

The Energy Division within MFIE has the responsibility for monitoring and regulating energy supply by interacting closely with all of the institutions involved in the energy sector. In particular, the Energy Division is responsible for developing policy and administering such policies with respect to the sector’s participants. Some of the Energy Division’s specific responsibilities include:

- Issuing licenses and leases for all oil exploration and production
- Advising on petroleum product prices
- Promoting the use of renewable energy technologies
- Promoting the effective use of energy.

Broadly, energy policy in Barbados over the past few years has aimed at ensuring the security of energy supply, and making the further development of these supplies sustainable.

B.2 The Fair Trading Commission

The Fair Trading Commission (FTC) was established in January 2001 under the Fair Trading Commission Act. The FTC evolved from its predecessor, the Public Utilities Board, which was responsible for regulating public utilities (such as electricity and telephone services) from 1955 until 2001. The further development of Barbados saw the need for a new body with a broader mandate to deal with other areas that had become important such as fair competition and consumer rights. The FTC is responsible for utility regulation, ensuring fair competition and ensuring consumer protection.
The duties of the FTC are to:

- Determine the principles, rates and standards of service for regulated service providers
- Monitor the general business conduct of firms
- Investigate possible breaches of the Acts administered by the FTC
- Educate and inform businesses and consumers about the requirements of these Acts
- Take enforcement action when needed.

The FTC is a separate entity with autonomy from the Ministry of Trade, Industry and Commerce, to which it reports administratively. The Utility Regulation Division of the FTC regulates two utility companies: Cable & Wireless (Barbados) Ltd. and The Barbados Light & Power Company Ltd. This Division oversees rates and service standards, and investigates queries and complaints.

In setting rates for service providers, the FTC is required to be fair and reasonable. In accordance with the principles established under the FTC Act or set out in rules, orders or regulations, in setting rates the FTC shall take into account:

- The rates being charged by competing service providers for supplying a similar utility service
- The standards of service being offered by the service provider and by competing service providers
- The return on the rate base
- The rate of inflation in the economy for any preceding period as may be considered appropriate
- The prospective increases in productivity by the service provider.

The decisions of the FTC are subject to judicial review on points of law.

The FTC obtains budgetary support from Government budget, and from taxes which are levied on the entities regulated by the Commission.

A recent World Bank study of regulatory authorities ranked the FTC among the top group due to its mechanisms and procedures for guaranteeing its autonomous administration.\(^1\)

The Commission does not itself have the power to impose fines and penalties on the service providers who are in breach of the URA. Instead, under Section 31 of the FTC Act, the Commission has the power to institute proceedings in the High Court to have the matter determined.

Service providers who fail to comply with an order of the Commission are liable, upon conviction in a court, to a fine of BB$100,000 and, in the case of a continuing offence, BB$10,000 for each day that the offence continues. Every director and officer of the service provider is also subject to prosecution under the FTC Act for non-compliance with and

order of the Commission, and upon conviction in a court is also subject to a fine of BB$50,000 or imprisonment for 6 months or to both penalties, unless the director or officer can prove that all necessary means were taken to ensure compliance with the order.

Fines may also be imposed in the courts for the willful failure of a service provider or its directors or officers to provide information in a manner directed by the Commission or within the time requested by the Commission.

The Commission may, on its own initiative or at the request of any party, review and vary or rescind any decision or order made by it, but if a hearing had been required under the Act to arrive at its decision, a hearing must also be held to facilitate the altering, suspension or revocation of the decision.

Appeals of Commission decisions or rulings on points of law may be made to a Judge of the High Court. The Judge, after hearing questions of law, remits matters to the Commission with his findings and opinion which the Commission and the other parties are obliged to comply with.

The Commission does not have any powers to enforce its orders and prescribe penalties on its own, and all such powers are derived through and administered through the courts by a Judge of the High Court.

**B.3 The Barbados Light & Power Company**

The Barbados Light & Power Company Limited (BL&P) is a vertically integrated electric utility company responsible for the generation, supply and distribution of electricity. Its predecessor, the Barbados Electric Supply Corporation (BESC), was established in 1909, following the passage of the Electric Light & Power Act by the Barbados House of Assembly in 1899 and its coming into effect in 1907. In 1955, the BL&P was established to take over the local assets of the BESC. In November 1997, all of the Company’s shares were exchanged for shares in a new parent Company, the Light & Power Holdings Limited. On January 2, 1998, the Barbados Light & Power Company became a wholly owned subsidiary of Light & Power Holdings (L&PH). Sixty-three percent of the shares of L&PH are owned by approximately 2,800 Barbadian investors, of which the National Insurance Board is the largest, owning 23 percent of the shares. The remaining 37 percent of L&PH shares are owned by Canadian International Power Co. Ltd., whose parent company is the Leucadia National Corporation of the USA.

Below we review BL&P’s license, its recent rate review application, and its initiatives for RE and EE.

**BL&P’s license**

Based on the ELPA, the license granted to the Barbados Light and Power Company Limited (BL&P) to provide electricity under the Act is not an exclusive license. The license granted to BL&P was extended in 1986 pursuant to the BL&P (Extension of Franchise) Act, Cap 278 of the Laws of Barbados, and granted BL&P the right to supply energy for all public and private purposes in Barbados for a period of 42 years from August 1, 1986.

**BL&P’s Application for a Rate Review**

Pursuant to Section 16 of the URA, BL&P filed a Rate Review Application with the FTC on 8 May, 2009. The company’s tariffs have not been increased since the Public Utilities Board (PUB) granted an increase in its decision dated 12 May 1983. The company claims that its
basic electricity rates are not sufficient to allow it to meet its operating and maintenance expenses which have been increasing over the years, as well as to allow it to attract new capital to replace old plant which is now due for retirement. The regulatory framework under which BL&P operates allows the company to earn a rate of return by establishing a revenue requirement that is based on its reasonable cost of service.

In its application for a rate review, BL&P proposed the introduction of a new Time-of-Use (TOU) tariff, and Interruptible Service Rider (ISR), and a Renewable Energy Rider (RER) for small grid-connected renewable energy systems. BL&P has also proposed that the TOU tariff and the two riders should be implemented on a pilot basis for a period of 3 years before deciding whether those schemes should be implemented permanently. According to the application, the pilot tariffs would be implemented on a ‘research basis’ to gather information to see how best to fully implement the schemes. This approach seems acceptable to the FTC, and BL&P has not included any expenses or revenues relating to these pilot programs in the submissions for a review of its rates.

On 25 February 2010 (following a decision in January 2010), the FTC published an order2 in the “Application for a Review in Electricity Rates”3 submitted by BL&P on 6 May 2009. The FTC largely allowed the increases BL&P requested. Average bills will increase by around 5 percent (given a constant fuel price). The pilot rates (TOU, ISR, RER) were approved for application starting 1 July 2010, for a period of two years.

**BL&P’s initiatives for RE and EE**

For several years, BL&P has been attempting to wind energy into the electricity mix. As of November 2009, BL&P is awaiting a decision on its application to the Town & Country Development Planning Office to construct a 10MW wind farm at Lamberts, in the parish of Saint Lucy. The company has completed a comprehensive Environmental Impact Assessment on the project. The Lamberts site has long been identified as a preferred location for wind energy development, and is included in the National Physical Development Plan for this kind of wind energy development. BL&P has stated its intention to continue to pursue this and other wind energy opportunities. As of June 2010, the Town and Country Development Planning Office of Barbados is expected to give development approval to the project.

BL&P is also preparing for the interconnection of small, customer-owned RE systems (solar photovoltaic and wind systems), which would be subject to a Renewable Energy Rider. These RE units, generally less than 5 kilowatts in size, are designed to connect directly to a customer’s electrical panel and offset the amount of energy required from the grid, with any excess feeding back into the grid. It is anticipated that the necessary technical and regulatory framework for the interconnection of this small RE systems would be in place sometime in 2010. It is unclear whether the RER—considering the price that BL&P proposes to pay for the energy from the RE systems and its limited duration—will be sufficient to ensure the viability of small grid-connected renewable energy systems.

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The company continues to promote energy efficiency among its customers—as the proposed Time of Use and tariff and Interruptible Service Rider show—and also strives to be efficient in its own operations. Technical losses arising from the transmission and distribution of electricity were 6.3 percent for 2008—they are among the lowest in the region, and comparable to the levels of utilities in Europe and North America.

Finally, BL&P has discussed with the Government the benefits associated with a proposal to import natural gas and, together with the project’s proponents, perseveres in its efforts to bring the project to fruition. Importing natural gas from Trinidad & Tobago via an undersea pipeline also offers a means by which Barbados can secure a clean source of fuel, and do so on terms that provide price stability over the longer term.

B.4 The National Petroleum Corporation

The National Petroleum Corporation (NPC) is a public corporation established as successor to the Natural Gas Corporation by the National Petroleum Corporation Act, Cap 280. That Act came into effect on April 1 1981. The Corporation’s primary function is the sale of piped natural gas for domestic, commercial, and industrial use. Its mission is to provide an adequate, reliable, safe, and efficient gas service to customers at a reasonable cost.

The Corporation’s general functions of production of crude oil, natural gas and liquefied petroleum gas are carried out by an associated company, the Barbados National Oil Company Limited (BNOCL). Since January 24 1996, the Corporation holds 24.5 percent of the equity in BNOCL, while the Government holds 75.5 percent. The Corporation is directed by a Board of Directors appointed by the Minister responsible for Energy.

B.5 The Barbados National Oil Company Limited

The Barbados National Oil Company Limited (BNOCL) was established in 1983, when the Government bought out the interest of Mobil Oil in Barbados. A small portion of the petroleum that Barbados requires is produced from onshore wells located at Woodbourne in St. Phillip. Barbados has been producing crude oil and other products for many years, satisfying up to 30 percent of local demand on some occasions. However, because of declining production, the current output of approximately 1,000 barrels per day represents only about 10 percent of Barbados’ fuel requirements, the remainder of which are imported.

Crude is no longer refined in Barbados. BNOCL sends its crude production to PETROTRIN, the state-owned oil refinery of Trinidad and Tobago to be refined in an exchange arrangement for refined product. The fuel oil received in exchange for the crude supplied by BNOCL only provides part of the amount of fuel oil required for Barbados’ consumption. BNOCL has entered into an arrangement with PETROTRIN whereby it receives a discount on the products sold to Barbados.

B.6 The Barbados National Terminal Company Limited

The Barbados National Terminal Company Limited (BNTCL) is a subsidiary of BNOCL. Initially, BNOCL would source and freight petroleum products to Barbados and ownership would pass to BNTCL at the ship’s flange. BNTCL would then store and sell products to users. The commercial relationship between BNOCL and BNTCL changed in 2005—now BNTCL is only responsible for storage of products. The new arrangements mean that BNTCL now operates only as a terminal facility, charging a throughput fee for product moved through its facilities.
BNTCL will move the fuel oil product through the ESSO Holborn terminal which it is leasing, and a newly installed pipeline. BNTCL has also built a pipeline between its Fairy Valley Terminal and BL&P’s generation facility at the Seawell generation station. The new pipeline became operational early in 2006.
Appendix C: Potential Renewable Energy Technologies

In this Appendix we describe renewable energy (RE) technologies that could contribute to expanding the use of renewable energy in Barbados. First we describe solar technologies—solar photovoltaic, solar thermal, and hybrid photovoltaic/thermal. We then turn to wind, biomass cogeneration, waste to energy (Appendix D provides a more detailed assessment of the viability of waste to energy technologies in Barbados, and their environmental impact). Finally, we describe seawater air conditioning (we discuss two other promising ocean technologies—Ocean Thermal Energy Conversion, and Ocean Wave Energy Conversion—which however are not yet proven commercially, in Appendices E and F, respectively).

For each RE technology, we provide a table that summarizes its key features, estimated energy production, and cost to generate the energy. Here we describe the key items contained in the tables:

<table>
<thead>
<tr>
<th>Key features and estimated savings of RE Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scale of Potential Installations</strong></td>
</tr>
<tr>
<td><strong>Typical Installed capacity (in Kilowatts)</strong></td>
</tr>
<tr>
<td><strong>Capacity Factor</strong></td>
</tr>
<tr>
<td><strong>Unit capital cost (in US$)</strong></td>
</tr>
<tr>
<td><strong>O&amp;M costs per year (in US$)</strong></td>
</tr>
<tr>
<td><strong>Lifetime (in years)</strong></td>
</tr>
<tr>
<td><strong>Output per kW capacity per year (in kWh/kW)</strong></td>
</tr>
<tr>
<td><strong>Annual Output (kWh/year)</strong></td>
</tr>
<tr>
<td><strong>Long Run Marginal Cost (US$/kWh)</strong></td>
</tr>
</tbody>
</table>

C.1 Solar Photovoltaic

Solar energy is fairly consistently available throughout the year in Barbados. However, it will vary with the orientation, shading, and tracking system employed. Table C-1 quantifies the radiation available under various orientations and tracking methods.

We examined the following solar photovoltaic (PV) technologies and mountings:

- Thin Film
- Mono/Poly Crystalline Silicon (c-Si)
- Tracking, Single and Double Axis
- Low Concentration PV
- High Concentration PV
Each of these technologies and mounting systems has advantages and disadvantages. The features and benefits of each are summarized below.

**Table C-1: Solar Radiation for PV systems**

<table>
<thead>
<tr>
<th>Description</th>
<th>kWh/m2/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Surface, 13 deg, Total (Global) Radiation 1/</td>
<td>1,948</td>
</tr>
<tr>
<td>Single Axis Tracking, 13 deg, Total (Global) Radiation</td>
<td>2,416</td>
</tr>
<tr>
<td>Double axis tracking, Beam (Direct) Radiation</td>
<td>1,518</td>
</tr>
</tbody>
</table>

Note: *1/ The analysis was performed using hourly TMY2 data from Husbands, Barbados at coordinates N 13 06 W 59 36 42. It is reasonable to assume that radiation data will be consistent across the island of Barbados. The annualization and tracking simulation was performed using TRNSYS a transient simulation analysis tool specifically designed for analysis of solar applications. It should be noted here that mono-crystalline cells are not as efficient at converting diffuse radiation; global radiation figures are assumed for simplicity making the HCPV performance ratios conservative.

**Thin Film**

A variety of substances are used to generate so-called thin film PV cells including amorphous silicon (a-Si), cadmium telluride (CdTe), and copper indium gallium selenide (CIGS). Typical panel efficiencies for this technology range from 7 percent to 10 percent. These efficiencies are not very competitive with conventional mono-crystalline technologies, but the cost to produce these cells is much lower.

Research is ongoing for these technologies and shows continued promise to reduce costs. It uses much less refined silicon per panel, making them more affordable, and is considered more robust than other types listed below. Despite having a lower efficiency and inherently taking up more mounting space, it is less affected by partial shading and mounting angle. This allows roof space unavailable to other technologies to be more fully utilized. This is further enhanced when wired in a massively parallel array and mated with an appropriate power inverter. Installed cost may be modestly higher due to an increased number of panels but annual energy output has been proving to be 10-20 percent higher than crystalline panels due to better thermal loss coefficients and better incident angle modifiers. Small panels have been formed into shingles and, with minimal training, have been installed by roofers into a “building-integrated photovoltaic” (BIPV) roof. Whether for a more unified, integrated appearance or a slightly higher annual return, thin film technologies like a-Si have many advantages besides low cost.

**PV Thin Film, Fixed**

<table>
<thead>
<tr>
<th>Scale of Potential Installations</th>
<th>Small</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Installed capacity (in Kilowatts)</td>
<td>2.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Capacity Factor</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
<td>10,000</td>
<td>200,000</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
<td>120</td>
<td>2,100</td>
</tr>
</tbody>
</table>
Mono/Poly Crystalline Silicon (c-Si)

Mono- and Poly-crystalline panels (single or multiple wafer sections of silicon, respectively) have long held the title of highest power output per a given area (with 15 to 20 percent efficiency), with commercial mono-crystalline panels leading the way. Although this helps with lowering the area of panels needed, partially shaded, off-angle or hazy sunlight tends to more rapidly diminish these panels’ output. A new generation of panels has been announced that merges the benefits of both a-Si and c-Si to achieve efficiencies as high as 23 percent. These panels may be considered where space is an issue or there are many cloud-free days.

### PV High Efficiency Fixed

<table>
<thead>
<tr>
<th>Scale of Potential Installations</th>
<th>Small</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Installed capacity (in Kilowatts)</td>
<td>3.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Capacity Factor</td>
<td>19%</td>
<td>19%</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
<td>18,000</td>
<td>250,000</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
<td>180</td>
<td>2,100</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Output per kW capacity per year (in kWh/kW)</td>
<td>1,624</td>
<td>1,624</td>
</tr>
<tr>
<td>Annual Output (kWh/year)</td>
<td>4,872</td>
<td>81,200</td>
</tr>
<tr>
<td>Long Run Marginal Cost (US$/kWh)</td>
<td>0.36</td>
<td>0.29</td>
</tr>
</tbody>
</table>

Tracking, Single and Double Axis

Any type of PV panel will increase its output if it is able to follow, or “track”, the sun across the sky. As it is more affected by off-angle/diffuse light, mono c-Si is perhaps best suited to be mounted in this way. Based on a typical meteorological year in Barbados, single-axis tracking will give about a 22 percent increase in global radiation compared to a fixed mounting system. Using a dual axis system delivers a 26 percent increase in global radiation. For technologies that utilize only the beam radiation (for example, a High Concentration PV), tracking systems are mandatory. Single axis tracking yields a 35 percent increase in incident beam radiation, while dual axis yields a 40 percent increase over a fixed system.
Tracker technology has now sufficiently evolved into a common, low maintenance, low energy loss method of leveraging investments in PV. A single axis – mono c-Si system can be an effective combination to improve the economic yield from an array (see Table C-2 below).

### Table C-2 Annual Radiation per Radiation Type and Tracking Method

<table>
<thead>
<tr>
<th>Radiation Type and Tracking Method</th>
<th>Annual Radiation (kWh/m²)</th>
<th>Ratio of Improvement Relative to Base (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Horizontal</td>
<td>1,948</td>
<td>Base Global</td>
</tr>
<tr>
<td>Global Fixed 13° Angle</td>
<td>1,977</td>
<td>1.015</td>
</tr>
<tr>
<td>Global Single Axis Tracking</td>
<td>2,416</td>
<td>1.222</td>
</tr>
<tr>
<td>Global Dual Axis Tracking</td>
<td>2,491</td>
<td>1.260</td>
</tr>
<tr>
<td>Beam Fixed 13° Angle</td>
<td>1,080</td>
<td>Base Beam</td>
</tr>
<tr>
<td>Beam Single Axis Tracking</td>
<td>1,455</td>
<td>1.348</td>
</tr>
<tr>
<td>Beam Dual Axis Tracking</td>
<td>1,518</td>
<td>1.406</td>
</tr>
</tbody>
</table>

**Low Concentration PV**

In order to reduce the cost of a PV array, low cost optics (lenses or reflectors) can be employed instead of adding more expensive silicon panels. Since concentrating two or three “suns” worth of global (diffuse and beam) radiation will increase the amount of power as well as heat. Low concentration does not proffer sufficient reduction in cell area to justify high cost, high efficiency cells, therefore conventional mass produced cells are utilized. Conventional cells have a high thermal loss coefficient; to prevent magnification of the thermal loss, passive heat sinks are often attached to the back of the PV panels. Without these, power output gains will drop off as temperature rises (more so for c-Si than a-Si panels).

### LCPV Single Axis Tracking

<table>
<thead>
<tr>
<th>Scale of Potential Installations</th>
<th>Small</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Typical Installed capacity (in Kilowatts)</strong></td>
<td>5.0</td>
</tr>
<tr>
<td><strong>Capacity Factor</strong></td>
<td>22%</td>
</tr>
<tr>
<td><strong>Unit capital cost (in US$)</strong></td>
<td>23,750</td>
</tr>
<tr>
<td><strong>O&amp;M costs per year (in US$)</strong></td>
<td>400</td>
</tr>
<tr>
<td><strong>Lifetime (in years)</strong></td>
<td>20</td>
</tr>
<tr>
<td><strong>Output per kW capacity per year (in kWh/kW)</strong></td>
<td>1,970</td>
</tr>
</tbody>
</table>
### High Concentration PV

High efficiency cells cost many times more than conventional cell technologies. Therefore, the use of high concentration optics is necessary to reduce the effective cost of the cells. Standard test conditions give rise to the definition of "one sun" corresponding to the irradiance and spectrum of sunlight incident on a clear day upon a sun-facing 37°-tilted surface with the sun at an angle of 41.81° above the horizon. A magnification factor of 1000 suns means 1000X magnification and results in 1/1000 the required cell area for the same energy collection.

Optics and double axis tracking must be used to concentrate the sunlight onto the cell surface. Due to the significant heating, passive or active cooling mechanisms are required to dissipate the heat. Active cooling systems can garner an additional benefit by collecting the useful waste heat. Each junction in a triple-junction semiconductor is optimized for a fraction of the solar spectrum which enables about 35 percent system efficiency. A comparison of available radiation multiplied by typical system efficiencies highlights the relative performance of each technology on a unit area basis. The real advantage of High Concentration PV systems is in applications where space is limited. For example, in an application such as Mall International, the 79 percent increase in annual energy per unit area can be very significant. Even with the entire roof top covered in HCPV panels, only a fraction of the annual energy could be met. If conventional fixed arrays were used, that fraction would be nearly halved.

### HCPV Dual Axis Tracking

<table>
<thead>
<tr>
<th>Scale of Potential Installations</th>
<th>Small</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Installed capacity (in Kilowatts)</td>
<td>5.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Capacity Factor</td>
<td>20%</td>
<td>19%</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
<td>32,250</td>
<td>172,500</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
<td>400</td>
<td>3,700</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Output per kW capacity per year (in kWh/kW)</td>
<td>1,786</td>
<td>1,624</td>
</tr>
<tr>
<td>Annual Output (kWh/year)</td>
<td>8,930</td>
<td>81,200</td>
</tr>
<tr>
<td>Long Run Marginal Cost (US$/kWh)</td>
<td>0.36</td>
<td>0.23</td>
</tr>
</tbody>
</table>
Comparison of PV Technologies

The first column shows an annual average global radiation (diffuse light and direct beam radiation) of 1,977 kWh per square meter per year that would be seen by a typical flat flat panel with a fixed orientation. The second column represents the benefit of single-axis tracking with a 24 percent increase in available energy to 2,416 kWh per square meter per year. This would be representative of the addition of single axis tracking to a flat panel technology. The third column shows a drop in available radiation with the dual access tracking because it includes only beam radiation. With high concentration systems, only the beam radiation is available.

However, these figures are incomplete without also considering the system efficiencies. If the factors that affect system efficiency are included (such as inverter losses, series shading effects, cell miss-match etc.), a mono-crystalline array may achieve a system efficiency of 15 percent. Triple junction high concentration PV arrays have demonstrated 35 percent system efficiency (the cells actually have a higher efficiency of around 42 percent). When the efficiencies are accounted for, the following table projects the relative annual energy output per unit area.

**Table C-3: Relative Annual Energy Output per Unit Area**

<table>
<thead>
<tr>
<th></th>
<th>Fixed Surface, 13° Total Global Radiation</th>
<th>Single Axis Tracking, 13°, Global Radiation</th>
<th>Double axis tracking, Beam (Direct) Radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual output (kWh/m²/year)</td>
<td>1,977</td>
<td>2,416</td>
<td>1,518</td>
</tr>
<tr>
<td>Panel Efficiency (percent)</td>
<td>15%</td>
<td>15%</td>
<td>35%</td>
</tr>
<tr>
<td>Output w/ Efficiency (kWh/m²/year)</td>
<td>297</td>
<td>362</td>
<td>531</td>
</tr>
<tr>
<td>Improvement over base (percent)</td>
<td>Base</td>
<td>22%</td>
<td>79%</td>
</tr>
</tbody>
</table>

The single axis tracking will yield 22 percent more energy than the fixed array. However, the advantage of the High Concentration PV array is 47 percent (531/362) higher than single axis tracking and 79 percent (531/297) higher than a fixed array.

This discussion pertains to output per unit area, not a levelized cost of energy in terms of dollars per kWh. However, some conclusions may still be drawn. Clearly, the single axis tracking could have a similar cost of panels and balance of system but would yield 22 percent more energy per year. The mechanical tracking systems available today represent a much smaller fraction of the system cost than earlier systems. Also, the cost of energy has increased dramatically, thereby greatly reducing the payback for the additional tracking complexity. This is the justification for single axis tracking systems when using conventional cell technology.

C.2 Solar Thermal

Capturing the heat from the sun is one of the most efficient ways to harvest this renewable energy. Barbados has a great potential for solar thermal. In fact, there is already a good penetration of solar hot water system in the residential sector. However, there is still
There are two main types of solar collectors utilized for low grade thermal applications: flat plate and evacuated tubes. Both technologies have pros and cons and are effective when used for the right application.

Flat plate panels are the most common type of solar collectors. These are widely-used in Barbados. A flat plate collector is an insulated box with a glazed cover, an absorber, and copper pipes. The solar radiation passes through the glazed cover and heats the absorber. The circulation water in the pipes captures the thermal energy. The water can move by natural convection to an elevated tank or be actively pumped through the collector. Intercept efficiency is defined as the efficiency of the collector when the average temperature of the panel is equal to the ambient temperature i.e. there are no losses or gains from the environment. The intercept efficiency for flat plate collectors may be as high as 80 percent but decreases rapidly with the increased difference between the temperature of the heated fluid and the ambient temperature.

Another type of solar collector uses evacuated glass tubes in order to reduce the heat loss to the surroundings. The absorber is located inside the tube and will be heated by the sun radiation which passes through the glass. The vacuum tube greatly reduces the conduction and convection losses to the environment. The maximum operating temperature of these collectors is over 100°C. The collector has multiple tubes side by side and the fluid is heated into the header or circulated through the tubes. The intercept efficiency of an evacuated tube collector will be slightly lower than a flat plate collector. However, the efficiency of the collector will be less impacted when the temperature difference between the heated fluid and the surrounding increases, therefore maintaining a higher efficiency even with a higher operating temperature. This makes evacuated tube collectors particularly better suited to providing process heating in the temperature range from 80-90°C.

<table>
<thead>
<tr>
<th>Solar Water Heaters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale of Potential Installations</td>
</tr>
<tr>
<td>Typical Installed capacity (in Kilowatts)</td>
</tr>
<tr>
<td>Capacity Factor</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
</tr>
<tr>
<td>Output per kW capacity per year (in kWh/kW)</td>
</tr>
<tr>
<td>Annual Output (kWh/year)</td>
</tr>
<tr>
<td>Long Run Marginal Cost (US$/kWh)</td>
</tr>
</tbody>
</table>

### C.3 Hybrid Photovoltaic/Thermal

Photovoltaic/Thermal (PV/T) collectors convert solar radiation into both electrical and thermal energy. In PV/T systems heat transfer fluid actively cools solar cells and recovers waste heat. The major benefits of PV/T systems are the reduction of the roof area required for mounting, the increase in the cell efficiency from actively cooling the collector, and the low installation and material costs (compared with similar PV systems).

PV/T systems can be used for residential, commercial, or industrial applications. Domestic hot water and electricity can be produced by the same system for residential and commercial consumers. The High Concentration PV/T is best suited for industrial processes. The concentrator will produce heat at a higher temperature, which can preheat boiler feed-water or even directly produce steam. Another application of high concentration PV/T is using high grade thermal heat to operate an absorption chiller for air conditioning. Also, high concentration allows the usage of high efficiency cells which results in higher electrical output and reduced required footprint.

<table>
<thead>
<tr>
<th>PV/T, Fixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale of Potential Installations</td>
</tr>
<tr>
<td>Typical Installed capacity (in Kilowatts)</td>
</tr>
<tr>
<td>Capacity Factor</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
</tr>
<tr>
<td>Output per kW capacity per year (in kWh/kW)</td>
</tr>
<tr>
<td>Annual Output (kWh/year)</td>
</tr>
<tr>
<td>Long Run Marginal Cost (US$/kWh)</td>
</tr>
</tbody>
</table>
The annual output shown above is based on 290 kWh electrical output and 1053 kWh thermal output for a 1.0 kW rated system. An equivalent output PV system (fixed thin film) would cost $811. An equivalent output solar thermal panel would cost $907. The total for the separate system types yielding identical energy output would be $1,720. This is reflected in the lower long run marginal cost of this option. Hence there is a significant cost savings potential to deliver these energies using the hybrid PV/thermal solution.

This would not necessarily result in an increased penetration in the renewable energy matrix. A fraction of consumers who would have purchased both systems separately might choose instead the lower cost PV/Thermal option. Only a small number of additional consumers are anticipated to be enticed by the incremental benefit of the PV/thermal technology. Rather than actually changing the RE grid mix, this option is more likely to change the technology mix. There might be only a slight increase in the fraction of RE supplied in either thermal or electric forms.

C.4 Wind Energy

Wind energy development is generally accepted as an important economic, social and environmental opportunity. It is an important technology to deploy in the efforts to lessen energy-related greenhouse gas emissions which are influencing, and will continue to influence, the variability of our climate.

Between 1997 and 2007, the wind energy industry saw a ten-fold increase. Despite the numerous benefits of utilizing wind energy as a renewable electricity source, this technology is not feasible or cost-effective in every location. This section will provide an assessment of the local wind resource in the Barbados area and a discussion of the feasibility of deploying wind turbines for electricity generation in grid mix.

Wind Turbines

Wind turbines are structures that produce power by capturing the kinetic energy in surface winds created by the sun and converting it into energy in the form of electricity. Wind turbines use the mechanical power generated by the turning of the blades to turn a generator located in the nacelle unit of the turbine. With large turbines, the generator produces electricity that is carried by cables to transmission lines that connect to the larger electrical grid. Small turbines can connect directly to homes and site-based business operations.

Key factors that affect the power produced by wind turbines are the strength of the wind, the area swept by the rotor and the height of the turbine. Generally, a turbine’s capacity to produce power is proportional to the strength and quality of the wind resource (e.g., not too strong, lack of turbulence, average speed), the larger the radius of the area swept, and the greater the height of the tower. It is important to note that even small increases in wind velocity will significantly affect the turbine’s generating power so siting and design decisions that are conducive to increasing the capture of greater wind velocity have an important effect on the amount of energy produced and the economic viability of the development. Advances in technology continue to result in more efficient turbines that can adapt to a broader range of siting environments.

Understanding the Quality of the Wind Resource

To evaluate the potential viability of any wind energy system, a detailed, on-site analysis with an anemometer measuring wind speed at the exact height of the hub of the chosen turbine
must be conducted. Potential off-grid or customer generators may even use several anemometers mounted at different heights and / or locations to provide more detailed data. Wind assessments are generally conducted at the site for no less than one full year. Indeed, Wind Energy Developers have highly sophisticated methods of measuring the characteristics of the wind at the precise location of proposed turbines.

While wind speed is the most important factor to consider when determining the quality of wind at a given site, it is not the only factor. Wind assessments also consider:

- **Wind Speed Distribution** – the pattern of wind speed changes over time. The ideal wind resource has relatively stable high speeds
- **Daily and Seasonal Wind Cycles** – differences in wind speed and strength over the course of a day or between seasons. Ideally, wind qualities for viable generation will match those times when electricity is needed most (e.g., during the daytime, hottest days of the year, peak usage hours)
- **Wind Direction** – While wind direction changes, it is important to know which directions provide the best winds for electricity production, and the percentage of time that the wind blows from that direction
- **Wind Shear** - Wind shear is the increase in wind speed at greater heights above ground. Because wind speed varies with elevation, it is important to assess the wind at the height which you expect to install the hub of the turbine itself
- **Air Pressure and Temperature** - Air pressure and temperature affect the amount of energy in the wind to a minor degree. Regional climate data is adequate for estimating pressure and temperature influences
- **Obstacles** - When wind flows around buildings and other structures in the landscape, it slows down or becomes turbulent. A wind turbine should be placed in a location where the influence of obstacles is minimized
- **Roughness** - The terrain and type and density of vegetation on the landscape creates ‘roughness,’ compared to a completely flat surface. This texture of a landscape, whether created by natural features or built structure, influences the behavior of the wind blowing across it. Wind turbine generators tend to analyze roughness within a 30 kilometer radius around a proposed wind site.

The cumulative wind resource quality and expected viability of a wind generation system at a particular site determines productivity—a combination of the maximum potential energy in the wind (given the characteristics of the site, surrounding area and wind) and the machine power output (of the chosen machine).

Barbados Light and Power has been progressing a 10MW wind farm development in the Lambert area. Based on BL&P’s studies, the wind regime in Barbados is quite favorable with a 30 percent capacity factor (typical for wind farm developments is a 30 percent capacity factor). For micro wind the capacity factor is reduced appropriately due to the cut-in and cut-out wind speeds typical for the much smaller blade diameters hence the 26 percent capacity factor assumption. Actual capacity factor are dependent on the site specific wind speed profile in conjunction with the technology specific power curve. The wind resource, unlike solar, will vary dramatically based on the surrounding topography, obstructions, and
altitude. Off-shore wind farm sites enjoy no obstructions and will generally have higher annual average wind speeds and associated capacity factors.

The annual average wind speed varies in the range of 6.1-8.3 m/s at a hub height of 80m.\(^4\)

### Wind Energy

<table>
<thead>
<tr>
<th>Scale of Potential Installations</th>
<th>Small</th>
<th>Utility (On-Shore)</th>
<th>Utility (Off-Shore)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Installed capacity (in Kilowatts)</td>
<td>10.0</td>
<td>10,000.0</td>
<td>50,000</td>
</tr>
<tr>
<td>Capacity Factor</td>
<td>26%</td>
<td>30%</td>
<td>40%</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
<td>55,000</td>
<td>18,600,000</td>
<td>85,488,000</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
<td>1,100</td>
<td>372,000</td>
<td>1,728,173</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Output per kW capacity per year (in kWh/kW)</td>
<td>2,278</td>
<td>2,650</td>
<td>3,504</td>
</tr>
<tr>
<td>Annual Output (kWh/year)</td>
<td>22,776</td>
<td>26,496,000</td>
<td>105,120,000</td>
</tr>
<tr>
<td>Long Run Marginal Cost (US$/kWh)</td>
<td>0.26</td>
<td>0.11</td>
<td>0.13</td>
</tr>
</tbody>
</table>

### On-Shore Resource Availability

On-shore utility scale wind in Barbados is limited by available locations where appropriate setbacks from permanent residences can be achieved. A significant issue with the current permitting process is the criteria for setbacks. Presently World Health Organization defines safe noise limits at 45 dB. This is a conservative limit and is not conducive to wind farm development. Other standards base the requirement on an incremental limit above ambient for example: ambient noise +30 dB. The balance between environmental impacts of each technology feeding the grid should be carefully weighed and taken into consideration during the permitting process. Particularly onerous permitting requirements may be debilitating to the penetration of new viable renewable energy technologies.

Beyond the currently planned BL&P 10 MW wind farm, there are only 3-4 potential sites for additional on-shore capacity. Of these, presently only 1 of the potential sites satisfies the current setback criteria for noise. Larger turbines should have a smaller noise footprint but may raise other concerns regarding catastrophic failures. Again permitting barriers being raised may not be well founded in statistical risk mitigation processes, but rather on public perception or fears. Larger turbines also bring logistical issues with the transportation of turbine blades from port to the final site. Based on a road study performed by BL&P, only the 1 MW turbine blades could be transported given the current road access. However, it would be possible to air lift the turbine blades to site for final erection. This would permit

\(^4\) [http://www.3tier.com/firstlook/](http://www.3tier.com/firstlook/) analysis tool
the larger and more economical wind turbine selections in the 3-5 MW capacity to be installed with appropriate setbacks.

Based on the current turbine selection by BL&P at 1 MW size, and assuming three of the four potential sites are eventually approved, the maximum on-shore capacity might range from 12-16 MW. If the technical and permitting issues associated with larger turbines were overcome, then the onshore potential could be as high as 30-40 MW. We recommend that the larger turbine selection be carefully reviewed prior to final selection of the on-shore wind turbines. For the purposes of the present analysis, we assumed that 10 MW of on-shore capacity is developable and that any capacity beyond this would be off-shore.

**Off-shore Wind Energy**

The EWEA (European Wind Energy Association) has the longest experience with off-shore wind installations. A recent EWEA report\(^5\) (2009 data) addresses the cost differences between on-shore and off-shore installations from the European market perspective. We converted costs in Euros to US$ using a 1.4 exchange rate. It should be noted that the costs are based on construction in Europe, which generally has smaller onshore projects than in the US or Canada and may be more comparable to costs projected for Barbados.

Approximately 75 percent of the total cost of energy for a wind turbine is incurred as upfront capital investments. This includes the costs of the turbine, foundation, electrical equipment and grid connection. Although wind turbines require no fuel costs, their upfront costs are high compared to traditional thermal generation projects, such as gas and diesel. The cost of a typical 2 MW turbine installation is US$0.67 million/MW. O&M costs are US$1.7-2.1 cents/kWh over the lifetime of the turbine (although there is little O&M data beyond 15 years to verify the estimate). About 60 percent of O&M is actually devoted to maintenance, including labor and spare parts. The other 40 percent of O&M is for insurance, land rental/leases and overheads. Larger turbines generally have lower long run marginal costs. This relationship creates advantages for off-shore wind installations, which face fewer limits to turbine size.

Offshore wind accounts for only about one percent of installed wind power worldwide. However, in Europe alone there are over 3,000 MW of installed capacity providing sufficient data to estimate costs. Development is focused in northern Europe, around the North Sea and the Baltic Sea, where 20 projects have been constructed. Offshore wind is still about 50 percent more expensive than onshore wind. Due to the benefits of higher wind speeds and lower visual impact of large turbines, the higher investment costs are somewhat offset by increased revenues from higher capacity factors. For onshore turbines energy production is normally around 2,000-2,500 full load hours per year. By comparison, offshore turbines can achieve up to 4,000 full load hours per year (depending on the site)—potentially translating into 35-50 percent more production.

An issue that may impact Barbados is the increased cost of wind as it gains penetration in the total market. In Europe, the largest penetration recorded is by Spain in excess of 50 percent generation by renewables. The EWEA report notes that at wind penetrations of up to 20 percent of electricity demand, system operating costs increase by about 5-10 percent of the wholesale value of wind. This additional cost occurs because additional generation capacity is required to balance for wind (a necessity for spinning reserves for when the wind

\(^5\) Oceans of Opportunity, European Wind Energy Association, September, 2009
Balancing costs increase on a linear basis with wind power penetration. In Barbados, diesel generation on hot standby with some Dynamic Var Compensation systems in place to allow ride through of disturbances (line or generator tripping) would work well. Using solar with wind may level out the uncertainty of wind but there will still be a need to stabilize generation as wind dies down. Without energy storage or smart grid dispatch, one hundred percent capacity firming by diesel generation would be necessary.

The average capital cost of onshore wind in Europe is around US$1.73 million/MW. This compares to the US$1.92 million/MW that was reported for example in Portland, Oregon, USA and even higher costs in Canada—likely due to the cost of access to the North Coast sites and long transmission ties. European wind farms are generally close to the grid with much lower cost for access roads and transmission infrastructure costs.

Almost all global offshore wind capacity in the world is installed in shallow waters (shallower than 20 meters) and close to shore (no more than 20 kilometers) in order to minimize foundation and cable costs. For deep water offshore wind turbines, foundations need to be similar to oil platforms or possibly “floating” foundations. Floating foundations are currently under development (no floating foundations are known to be in commercial operation). Offshore capacity is around 50 percent more expensive to install, but offshore farms can be larger and less visually intrusive. The offshore “shelf” around Barbados is shallow enough to allow this type of construction but only within about one kilometer of the coast.

We estimate an investment cost of US$3.23 million/MW for offshore wind projects. Expected turbine and foundation costs are about 20 percent and 150 percent greater, respectively, than costs for similar onshore projects. Foundation costs typically comprise about five to nine percent of total project cost for onshore wind farms, but increase to over 20 percent of total project cost for offshore wind farms. Submarine grid ties are much more expensive for offshore wind farms, especially when compared to the cheap overhead grid ties allowed for some onshore farms. Similarly, maintenance is much more expensive in the event of an undersea failure. Buried sea cables, however, may mitigate such maintenance issues.

Off-shore wind regimes are more consistent and of a higher speed than on-shore regimes in similar locations. Better wind resources typically result in a capacity factor that is three to seven percent better offshore than onshore. The resulting output increase ranges from 12 to 20 percent.

**C.5 Biomass Cogeneration**

Biomass Cogeneration has been used by the sugar cane industry in Barbados for years. Currently the sugar cane industry burns bagasse in their boilers to generate steam for their processes. The steam is also used to generate electricity for the plant. No excess electricity is generated.

The BCIC has plans to consolidate the current Andrews and Portvale sugar mills into a single rehabilitated and refurbished factory at Andrews factory site. As part of these upgrades BCIC intends to optimize the co-generation of electricity for sale to BL&P, utilizing both bagasse from the cane and other biomass waste available from the Islands’ waste management facility.
This will include installing a new 8,200 kPa high efficiency steam boiler, one back pressure turbo alternator, one condensing turbo alternator complete with condenser and one cooling tower for the condensing turbine.

The Sugar Industry in Barbados has two seasons;

- A crush season of about 20 weeks from mid January to June
- An off crop from June to mid January (32 weeks).

The bagasse fuel is made and a portion consumed during the season. The remainder of this fuel would be stored for the off season power generation. In addition biomass fuel from the island waste would be transported to the factory throughout the year at an estimated 200 tons per day. In order to limit the amount of bagasse storage it is proposed that the Cogeneration Operation is split into three time periods with different amounts of electrical power available for export to the grid during any one period.

- Period one would be for the 20 week crushing season when bagasse fuel is being produced. Here the amount of average power available for export would be in the region of 11MW. The total power generated would be in the region of 17.5MW. The bagasse in storage would be minimal

- Period two would be the first 16 weeks of the off season. The power island would be shut down for maintenance and no power would be exported. However biomass waste fuel would continue to be brought in at 200 tons per day and stored

- Period three would be the second 16 weeks of the off season. The power island would be fired up using the waste fuel stored during the previous 16 weeks and the fuel arriving at 200 tons per day. The average power available for export would be in the region of 7.7MW while the total power generated would be approximately 10MW.

For the purpose of this study it is assumed that all the electricity generated is accounted for.

<table>
<thead>
<tr>
<th>Biomass Cogeneration</th>
<th>Utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale of Potential Installations</td>
<td></td>
</tr>
<tr>
<td>Typical Installed capacity (in Kilowatts)</td>
<td>20,000.0</td>
</tr>
<tr>
<td>Capacity Factor</td>
<td>90%</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
<td>59,526,599</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
<td>1,450,281</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
<td>20</td>
</tr>
<tr>
<td>Output per kW capacity per year (in kWh/kW)</td>
<td>4,319 (including power used by cane factory and that sold to the grid)</td>
</tr>
<tr>
<td>Annual Output (kWh/year)</td>
<td>86,389,333</td>
</tr>
<tr>
<td>Long Run Marginal Cost (US$/kWh)</td>
<td>0.11</td>
</tr>
</tbody>
</table>
C.6 Municipal Solid Waste to Energy

A Municipal Solid Waste (MSW) to Energy plant is an effective way of generating electricity while reducing the amount of waste sent to the landfill. Waste streams are readily available for use in such a plant. There are many different technologies that could be used, which are discussed further in Appendix D. Conventional combustion, more specifically mass burn moving grate systems, is the most conservative and reasonably viable approach capable of managing unprocessed MSW with variable composition similar to that which would be available in Barbados which is commercially proven. As such this technology was considered in the table below.

Conventional combustion covers a number of well-established technologies developed over 100 years ago for energy generation from municipal solid waste. The most common conventional approach is the use of mass burn moving grate systems to combust MSW feed streams. In mass burn systems, waste is fed into a combustion chamber onto one or more grates where several steps occur. The first step reduces water content to prepare material for burning. The next step involves primary burning which oxidizes the more readily combustible material while the subsequent burning step oxidizes the fixed carbon. Waste is burned in sub-stoichiometric conditions, where sufficient oxygen is not available for complete combustion. The oxygen available is approximately 30 to 80 per cent of the required amount for complete combustion which results in the formation of pyrolysis gases (flue gas). These gases are combined with excess air in the upper portions of the combustion chamber which allows complete oxidation to occur.

Mass burn technology applications provide long residence times on the grate(s) which in turn produces good ash quality (i.e., less non-combusted carbon). Newer facilities have greatly improved energy efficiency and usually recover export energy as either steam and/or electricity.

Operation and maintenance costs are estimated at US$299.6/kW/yr to operate the waste to energy plant. However, there are other non-energy savings that offset significant O&M costs. These include a reduction in the cost of building a new landfill and waste diversion savings. The net effect on O&M costs is O&M cost savings of -79.67/kW/year.

Based on a study conducted by Stantec in 2000, the Landfill O&M costs per year are estimated to be US$14 million (including direct costs, indirect costs and depreciation of the facilities) and the Capital cost for the Landfill is $15 million. It is assumed a landfill will last 15 years before a new landfill will be required. A mass burn waste to energy plant would reduce the amount of waste to a landfill by approximately one fifth. The result would be an extension of the life of a landfill to 75 years. This equates to an average cost reduction of US$800,000 per year.

In addition to savings attributed to landfill avoidance savings there are also significant savings in the operation and maintenance of the landfill with an 80 percent reduction of waste. Facilities and equipment will experience less wear and tear allowing for longer life. The savings includes a reduction in direct costs, indirect costs and depreciation of facilities attributed to waste diversion. It is anticipated the waste to energy plant will have 120,000 tons of waste go through the plant per year. With a mass burn technology plant 20 percent of this is turned into residual waste and will go to the landfill. The difference (96,000 tons) is avoided waste to the landfill. Assuming a waste diversion cost of US$45/tonne, this results in an annual savings of US$4,320,000 per year out of the US$14,000,000 stated above.
The combined reduction in costs equate to US$5,120,000 per year which results in a net O&M savings when combined with the O & M costs of the WTE plant.

There are other intangible benefits to a Waste to Energy plant. This will result in a significant reduction in landfill emissions and provide social benefits as well. The above cost estimate does not include decommissioning of landfills, finding new landfill sites, EIAs of new sites, potential carbon credits or excess costs for revised transportation routes. Also the sale of by products such as the ash for use in concrete or scrap metal found in the ash for recycling could be sold. A detailed full lifecycle analysis should be completed prior implementing a waste to energy plant.

<table>
<thead>
<tr>
<th>Municipal Solid Waste to Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale of Potential Installations</td>
</tr>
<tr>
<td>Typical Installed capacity (in Kilowatts)</td>
</tr>
<tr>
<td>Capacity Factor</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
</tr>
<tr>
<td>Output per kW capacity per year (in kWh/kW)</td>
</tr>
<tr>
<td>Annual Output (kWh/year)</td>
</tr>
<tr>
<td>Long Run Marginal Cost (US$/kWh)</td>
</tr>
</tbody>
</table>

**C.7 Seawater Air Conditioning (SWAC)**

Seawater Air Conditioning (SWAC) systems utilize the renewable energy from the deep sea cold water for cooling purposes and many other secondary applications. Barbados has some of the best SWAC potential in the world—and, thus, potential to achieve significant electricity demand reduction. The power consumed for air conditioning in a high density area could be reduced by more than 85 percent with the installation of a district cooling SWAC system. The main benefits from SWAC systems are the following:

- Large energy savings
- Constant energy availability
- Proven technology
- Short economic payback (three to seven years)
- Cost are nearly independent of energy price increase
- Environmentally friendly
- Cold seawater availability for secondary applications.
SWAC uses cold water from the deep sea to cool buildings. According to the Barbados Coastal Zone Management Unit, deep sea can be accessed one kilometer from the coast, where the sea bed descends sharply. At this location, the water temperature decreases predictably with the depth. The average surface temperature is 28°C and the temperature reaches a minimum of 4°C at a depth of roughly one thousand meters.

The main components of a SWAC system are the supply water pipeline, the effluent water pipeline, the isolation heat exchanger, the chilled water distribution system, and building cooling systems. In some systems, cold water storage can be incorporated to optimize pipeline utilization and meet peak cooling loads without over-sizing the supply pipeline.

**Figure C-1: Seawater Air Conditioning**

Every system working in a seawater environment has special requirements. Supply and effluent pipelines use high density polyethylene (HDPE) piping. HDPE is inert and will neither corrode in nor contaminate seawater. This pipeline material has several advantages and gives flexibility in design and ease of deployment. Several HDPE pipelines have been successfully deployed in seawater conditions. Additionally, a heat exchanger isolates the seawater and the chilled water loop. Titanium is used for the heat exchanger to eliminate corrosion and fouling. The chilled water distribution and building cooling systems are similar to conventional systems. In fact, a SWAC system uses established technology in an innovative way. All the necessary components exist and operate under the intended conditions.
Preliminary cost-savings calculations were performed for a SWAC district cooling system located near Needhams Point, Barbados. At this location, the district system could displace 2,000 kilowatts of air conditioning in a 600 meters radius area.

### Seawater Air Conditioning (SWAC)

<table>
<thead>
<tr>
<th>Scale of Potential Installations</th>
<th>Utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Installed capacity (in Kilowatts)</td>
<td>2,000.0</td>
</tr>
<tr>
<td>Capacity Factor</td>
<td>33%</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
<td>8,278,200</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
<td>331,200</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
<td>20</td>
</tr>
<tr>
<td>Output per kW capacity per year (in kWh/kW)</td>
<td>2,891</td>
</tr>
<tr>
<td>Annual Output (kWh/year)</td>
<td>5,781,600</td>
</tr>
<tr>
<td>Long Run Marginal Cost (US$/kWh)</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Secondary applications of SWAC systems include chilled-soil agriculture, aquaculture, desalination, and secondary cooling. Each secondary application can lead to significant additional revenue, increasing the return on investment.

Experts in SWAC systems determined economic viability according to the following factors:

- Offshore distance to cold water (shorter pipelines are have lower costs)
- Size of the air conditioning load (higher density cooling loads lead to greater economies of scale)
- Utilization of air conditioning systems (greater utilization increases savings)
- Local cost of electricity (higher costs imply greater savings)
- Complexity of the distribution system (district systems reduce cost)
- Marine construction infrastructure (Local contractors can reduce costs).

Considering all of these economic factors, Barbados has great potential for SWAC systems. Based on actual material and energy cost, SWAC systems are already economically justified compared to fossil fuels. Energy from SWAC is always available and can thus displace baseload generation. The cost of the energy produced by SWAC systems is nearly independent of the future energy cost. The average lifetime of the equipment in SWAC systems is 20 years. However, pipelines, which are the major initial cost, last up to 75 years.
Appendix D: Waste to Energy Technologies and Environmental Impact

Appendix E: Ocean Thermal Energy Conversion (OTEC)

The search for new sources of energy often neglects the renewable resources available from the ocean. The ocean has the potential to offer an endless supply of clean renewable energy, including wind, tidal, current, wave, and thermal energy. Before deciding whether to pursue renewable oceanic energy, all available technologies need to be explored to determine whether any of them are economically viable, and if so, where the projects incorporating those technologies should be located.

As the price of thermal energy—as oil, gas, and coal—increases, it is essential to investigate and improve alternative energy sources such as renewable ocean energy. Because of their isolation from most traditional sources of energy, island nations are in a particularly advantageous position to implement oceanic renewable energy. In addition, the process of thermal conversion generates a large amount of fresh water, which can be used as drinking water.

Two types of oceanic energy can be used to generate electricity: (i) thermal energy from solar irradiation and (2) mechanical energy from tides, waves, currents or winds. This Appendix emphasizes the use of ocean thermal energy in electricity generation, and provides a few recommendations regarding the potential for its development. The next Appendix covers the use of ocean mechanical energy. Ocean mechanical energy is relatively irregular and unpredictable. Ocean thermal energy, on the other hand, is fairly constant, and can be used as base load power thanks to the ubiquitous and consistent existence of thermal gradients between the surface layer and the deep ocean water.

### E.1 Ocean Thermal Energy Potential

Electricity is generated from ocean thermal energy through a heat-to-work conversion process that utilizes existing thermal gradients between the surface layer and deep water in the ocean. The potential of the ocean thermal energy is unlimited due to the daily replenishment by solar irradiation. In contrast to the intermittent nature of oceanic mechanical energy, oceanic thermal energy is a more consistent and reliable source of energy. Furthermore, it has reached the point of technical feasibility and pre-commercial feasibility. It should be closely observed for a potential upcoming readiness for industrial and commercial use.

In tropical oceans, there exist waters of different temperatures in layers. The surface layer can have a temperature of above 25°C down to the top of the thermocline, a thin layer of abrupt temperature change. A deep cold, thick layer near 4°C extends to the bottom with very little vertical temperature gradient within layers. This is shown schematically in Figure E-1. The temperature differences between the warm surface layer and the cold bottom layer range from 20°C to 25°C.

As one would expect, surface water temperatures are higher in equatorial waters, as shown on the map in Figure E-2, which leads to a greater differential between the surface and bottom layers in equatorial regions than would be found elsewhere in the world. This differential serves as a huge reservoir of energy, as heat exchange between the layers can be captured to produce electricity. However, this wealth of ubiquitous ocean clean energy potential has not yet been well tapped.
E.2 OTEC Technology

One approach to developing electricity from ocean energy is known as Ocean Thermal Energy Conversion (OTEC). This approach utilizes the temperature differences between the surface layer and the deeper water well beneath the thermocline through the process of evaporation and condensation to run a turbo-generator for electricity.

The idea of harnessing the power stored in the tropical oceans has existed for over a century. The idea was originally conceived by French physicist Jacques Arsene d’Arsonval in 1881, but real interest in the technology did not take off until the worldwide energy shortages of the early 1970s. Several countries conducted successful laboratory and at-sea experiments from the 1970s through the 1990s. Today, OTEC technology is much more advanced, but still in the pre-commercial stage. However, several research institutions and industrial companies have proposed and are actively pursuing the development of commercial scale facilities in various parts of the world.

Common OTEC Designs

OTEC operates as a heat engine that uses warm surface seawater to vaporize a working fluid. The vapor stream then turns a turbo-generator to produce electricity. Cold water pumped from the deep ocean condenses the vapor back to liquid as it exits the turbine. Current OTEC technology designs are:
1. **Closed-cycle**—a schematic of a simplified closed-cycle OTEC flow diagram is shown in Figure E-3. Warm surface water and cold bottom water are used to vaporize and condense a working fluid (generally, Ammonia or Propylene) that drives a turbine-generator.

2. **Open-cycle**—the sea water is flash-evaporated in a vacuum chamber, resulting in a low-pressure steam which is used to drive a turbine-generator. Cold water is used to condense the steam for producing fresh water.

3. **Hybrid-cycle**—this is a combination of the two aforementioned cycles, designed to produce electricity and desalinated drinking water.

**Figure E-3: How ocean power operates**

The science of OTEC is sound and relatively easy to understand. OTEC is a heat engine for power, basically similar to the car or jet engine. The difference is that the former operates under low temperature, low pressure, and low speed conditions—therefore, with low efficiency and low required maintenance. The latter (auto/jet engines) are usually very high speed, high pressure and very high temperature engines. From an engineering point of view, this is a key perceptive distinction in efficiency between OTEC and the high speed jet engines. To advance OTEC technology, the improvement of the overall efficiency of the OTEC system (including each and every component) is the key to success. Significant breakthroughs that promise major improvements in the efficiency of the OTEC system and reduction in the cost of manufacturing have been achieved by many university and industry researchers via innovative designs of heat exchangers, turbine components, condensers, and piping design and deployment technologies.
Recent Advances in Technologies

Many renowned scientists and engineers over the world have worked on OTEC technologies since the nineteenth century. In the United States, scientists and engineers in universities and private OTEC related industries, notably in Hawaii and in the Washington/Baltimore area, have worked diligently toward a better economic and more efficient OTEC system. In the design process for a cost-efficient OTEC system, scientists and engineers have improved the heat exchange efficiencies of all components, minimizing heating and cooling water flows, using adequate material at low costs, and minimizing the equipment sizes and weights in mind (Sea Solar Power International, 1980).

The new OTEC technologies and designs of components and systems (including heat exchanger, refrigeration, piping, pumping, weight, and amount of circulation water) have significantly improved performance, and have proven more sophisticated than those in the early development of the eighties. A recent sketch design of OTEC operation is shown in Figure E-4.

Figure E-4: Sketch of an ocean floating OTEC plant

Source: Sea Solar Power, Inc.

OTEC System By-Products

The open cycle of OTEC generates electricity and produces a large amount of drinking water. The closed cycle and hybrid OTEC also produce both with some minor modifications. OTEC can be used effectively to produce hydrogen, ammonia and methanol. Hydrogen is considered to be the clean energy carrier of the future. The deep ocean water can also be used for air conditioning (after cooling the condensers), for aquaculture fishery farming, and for agricultural food growths. All these valuable by-products have been demonstrated in Hawaii (Daniels, 2000). Japan has already experimented with using the deep nutrient ocean water to make beer and healthy soft drinks.
The current status of OTEC system technology has advanced to a very promising stage for future economic viability. It is estimated that there are ninety-eight nations and territories with thermal resources amenable to OTEC development over the tropical regions of the world. This represents significant market potential of up to 577,000 MW of new base load electric power facilities valued at more than several thousand trillion dollars under current market conditions (Takahashi and Trenka, 1996).

**OTEC Hydrogen**

Perhaps the largest contribution to human society and global climate change that OTEC will have is as supplier of hydrogen for the impending hydrogen economy in the future. The huge energy reservoir in the tropical ocean available via the OTEC process will require a transportable form of that energy to allow delivery to remote energy demand centers in far away temperate zones. This transport can be done in the form of ammonia, and then transformed to hydrogen by heating. The other attractive and versatile transportable energy form is liquid hydrogen.

There are prominent natural synergies between OTEC and hydrogen, especially liquid hydrogen (LH₂), which other renewable energy, such as wind and solar, do not possess. These include the following:

- Full and efficient utilization can be made of the investment in production capacity, because OTEC (unlike many other intermittent RE sources) is available 24 hours per day and 365 days per year. Also, OTEC systems (unlike fossil fuels, and some sources classified as renewable, such as geothermal or hydro) do not deplete the resource of the location where they are installed.

- The efficient production of hydrogen by electrolysis requires very pure water for the potassium hydroxide (KOH) solution. A small part of the OTEC process can be used to produce this pure water from the surface seawater, resulting high efficiency in electrolysis.

- Liquefying hydrogen with a Claude process requires an efficient heat sink to minimize process energy. The cold seawater that is used in the OTEC process provides this efficient heat sink.

- Liquid hydrogen is most efficiently transported by an ocean tanker. The off-shore OTEC hydrogen plant is already located on the transport medium, and therefore would result in the lowest cost for transport to market. From a global perspective, ocean transport distances of OTEC derived LH₂ are much shorter than the present system of oil transport from the Middle East around Africa to North America or Europe, or from the Middle East around India and the Malayan Peninsula to Japan.

The successful development of a global hydrogen economy will undoubtedly have to involve the largest renewable energy resource potential in the world—the tropical ocean. OTEC technology is the best way to tap into this virtually limitless thermal reservoir to produce hydrogen. Offshore OTEC plants, utilizing techniques already developed for accessing deep water oil fields, can be adapted to produce and liquefy hydrogen and ensure a sustainable supply of hydrogen from an environmentally benign, renewable resource for future generations.
E.3 OTEC on Demand

OTEC offers one of the most environmentally friendly, clean power production technologies under relatively low speed and low temperature conditions with very low operation and maintenance costs. OTEC can also produce millions and millions gallons of drinking water. The source for OTEC energy is supplied by the solar system free of charge, thus saving billions in refueling costs for generating power over conventional fossil fire plants. In addition, OTEC by-products from aquaculture, agriculture, and oceanic fishery farming are potential additional sources of food.

Technically, all essential components of an OTEC system have been demonstrated on pilot scales in Hawaii (Vega, 2002) and on some other world research campuses, although the economic viability of a multi-product OTEC system needs to be proven before extensive commercial applications will attract more private investors.

In summary, ocean renewable energy has the potential to provide low-cost baseload energy, improve energy security, reduce GHG emissions, and mitigate drinking water shortages. Mechanical forms of ocean energy—wave, tidal, and current—are still in early phases of research and development, and are presently considered inconsistent and intermittent sources of energy. Unlike mechanical energy, ocean thermal energy is limitless and can be used as base load power thanks to consistent thermal gradients between surface water and deep water in the ocean.

E.4 OTEC Potential for Barbados

Barbados seems to have suitable locations for OTEC development, especially along the east open ocean side of the island. However, a field investigation and study to decide the exact site recommendations must be undertaken to proceed with a realistic OTEC plan. Site selection will require more site visits, oceanic and atmospheric data, and numerical modeling simulations.

Several OTEC plants are at various stages of development throughout the world. In the US Lockheed-Martin has begun building a 15 MW OTEC plant in Hawaii that is scheduled to be completed within 2012. Lockheed-Martin has also begun planning to build another 100MW OTEC plant. Outside the US, Indian and Japanese companies are cooperating to build a 2MW OTEC plant in the Indian Ocean that is now near completion.

If developed, available OTEC energy along the equatorial regions alone can provide several hundred times the current need for energy over the world. We can make a preliminary OTEC assessment using available data from Barbados, and extrapolating with data from the USA. According to available oceanic data for the waters surrounding Barbados, the average water temperature drops quickly from 27.5°C at the surface to about 5°C near 700 meters offshore. This temperature profile in coastal waters suggests a high likelihood of finding a suitable OTEC site on-land in Barbados. Of course, a practical field survey and detailed investigation for sites is essential before planning and designing a new OTEC power plant.

Under a preliminary estimate based on available designs and analyses of OTEC plants under development or planned, a 15MW OTEC power plant in Barbados could have a 95 percent

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6 Dr Luis Vega, http://www.otecnews.org/articles/vega/11_market_potential.html
capacity factor, a capital cost of about US$130 million, O&M costs of about US$300,000 per year, a lifetime of 25 years, and an annual output of over 12GWh per year.

The following is a rough estimation of a basic cost analysis for a 15 MW OTEC power plant. This estimation is for reference only, without a specific site identified. The estimated costs are based on others’ designs and analyses of a similar OTEC plant, but do not consider specific figures on platforms, pipings, and manufacturers.

**References**


Appendix F: Ocean Wave Energy Conversion

Waves at the ocean’s surface can be used as a source of renewable energy. Wave energy utilization has the greatest potential at islands such as Barbados, because of the combination of several factors such as the availability of strong coastal ocean waves, long shoreline, lack of natural water resources, and the relatively high costs of other local energy sources. Technologies to harvest wave energy have been developed in the past few decades and several wave energy conversion devices have been successfully demonstrated in recent years.

The following briefly describes the favorable wave environment of Barbados, the application of wave energy to meet Barbados’ potential energy needs, a review of existing ocean wave energy conversion technologies, and two promising technologies applicable to Barbados for reference in future analysis.

F.1 Barbados and its Ocean Wave Energy Prospects

Large ocean waves associated with strong and constant trade winds along the east and north coast of Barbados (with total coastline over 35 km) create favorable conditions for surfing. The coral-based rocky shore discourages more recreational activities along these coasts. However, the environmental factors favor the development of ocean wave energy for generating electricity and/or fresh water.

Measure of Wave Power

Waver power, $P$, can be estimated by

$$P = \left(\frac{\rho g^2 T H^2}{32\pi}\right) \text{ Watt per meter (W/m) of wave crest length, or}$$

$$\approx 0.5 (H_s)^2 T \text{ kilowatt per meter (kW/m) of wave crest length}$$

Where:

- $\rho = \text{the density of seawater} = 1,025 \text{ kg/m}^3$
- $g = \text{acceleration due to gravity} = 9.8 \text{ m/s}^2$
- $T = \text{period of wave (s)}$
- $H = \text{wave height (m) for regular waves}$
- $H_s = \text{significant wave height (m) for irregular waves}.$

Estimates of Power Needed for Electricity and Water Desalination

This example is provided to illustrate potential for ocean wave energy in Barbados. The example makes the following assumptions:

- Electrical power consumption per person = 1 kW/day (for average U.S. citizen)
- Fresh water consumption = 227 liters/day or 227 L/day (for average U.S. citizen)
- Significant wave height = 1.5 m
- Wave period = 7 seconds
- Electricity conversion efficiency = 25 percent
According to the first equation above, the available wave energy is 7.875 kW/m. With 25 percent conversion efficiency, the net converted electric power will be 1.97 kW/m of wave crest width.

For a township of 1,000 people, daily electric need is 1,000 kW, which will require $\frac{1,000}{0.875} = 1,143$ m (about 1.2 km) of wave crest width. This is only about 3.4 percent of the available Barbados east coastline.

The power needed to generate fresh water for 1,000 people is estimated as follows. Assuming a desalination system operates at an average pressure of 60 atmospheres, pumping 379 kL of sea water per day to obtain 227 kL would require about 26.3 kW of electric power. For a 25 percent efficient electric conversion system, 105.2 kW of ocean wave power is required. The wave crest width needed to provide this power is $\frac{105.2}{3.5} = 30$ m. Note that the power needed for desalinated water is much smaller compared to that required for domestic electricity usage (about 10 percent).

### F.2 Types of Wave Energy Capturing Technologies

There are four major type of ocean wave energy conversion devices, differentiated based on their energy capturing principles. These are Wave Terminators (for example, the Oscillating Water Column by Energetech of Australia); Wave Attenuators (for example, the Pelamis system developed by Pelamis wave Power, Ltd. of UK; Point Wave Absorbers (for example, the PowerBuoy developed by Ocean Power Technologies of USA; and Wave Overtopping devices (for example, Wave Dragon developed by Wave Dragon of Denmark). Table F-1 lists the technical merits, concerns, costs and field test information about these devices.

#### Table F-1: Technical and Cost Data of Key Ocean Wave Energy Conversion Devices

<table>
<thead>
<tr>
<th>Device/Method</th>
<th>Technical Merits/Concerns</th>
<th>Installation Site</th>
<th>Available Capacity</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>PowerBuoy/Point Wave Absorber type</td>
<td>Build on well-established buoy technology; less affected by varying wave directions; modular design, easily expandable to array of units (e.g., wave energy farm); field tested for commercial application. Recommended for Barbados application. Concerns include impacts of marine growth and corrosion</td>
<td>Suitable for water depth of 30m or greater; work best under long period ocean swells</td>
<td>Pre-commercial products include: PB40 system (40 KW), PB150 system (150 KW), and PB500 system (500 KW)</td>
<td>PB40: US$1.7 M per system, PB150: US$2.4M per system, PB500: US$2.5M per system</td>
</tr>
<tr>
<td>Pelamis/Wave Attenuator type</td>
<td>Streamlined configuration minimized visual impact and improved structure stability; modular design, easily expandable to array of units (e.g., wave energy farm); field tested system for commercial application. Recommended for Barbados application. Concerns include long-term reliability of hinge mechanism</td>
<td>Could be moored in coastal or deeper ocean; work best under constant long period ocean swells</td>
<td>Pre-commercial products include: P750 system (750 KW)</td>
<td>P750: $4 M per system</td>
</tr>
</tbody>
</table>
Oscillating Water Column, CETO / Wave Terminator type

Can be installed onshore (e.g., next to breakwater, of shore), near shore (e.g., to 7 m water depth) or floating offshore; easy to design, operate and maintain for shore-based system. Concerns include stability of anchoring; corrosion, dynamic stability of moored OWC, and lack of adequate field testing data of pre-commercial products.

Suitable for shore-based installation; Water depth is important so that ocean wave energy is not significantly reduced at the site.

Variable depending on design (test of a 300 KW CETO reported)

300 KW CETO: $ 1 M per system

Wave Dragon, TAPCHAN/ Wave Overtopping type

Can be installed onshore (exposing to adequate wave height) or moored; design for shore-based system can be flexible to fit in shoreline configuration (e.g., TAPCHAN). Concerns include survivability in ocean storm, negative visual impact from non-conventional configuration above water surface, marine growth and corrosion, and lack of adequate field testing data of pre-commercial products.

Work best for land-based system where incident wave energy is not significantly attenuated and wave direction remains fixed, and tide range is small.

Designs up to 11 MW have been tested

No data available

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F.2.1 Promising Ocean Wave Energy Conversion Devices Applicable to Barbados

Based on the degree of maturity of technology for commercial application, the Pelamis wave attenuator device and PowerBuoy point wave absorber device are presented as candidates for Barbados.

Pelamis Wave Energy Converter

These devices are long multi-segment floating structures oriented parallel to the direction of the wave travel. The wavy ocean surface along the length of the device causes flexing where the segments connect. This flexing is connected to hydraulic pumps or other converters.

The Pelamis system was developed by Pelamis wave Power, Ltd. In Edinburg, UK. It has four 30 m long by 3.5 m diameter floating cylindrical pontoons connected by three hinged joints (see Figure F-1). Flexing at the hinged joints due to wave action drives hydraulic pumps built into the joints. A full-scale prototype system was successfully tested in 2004. The world first commercial system was deployed in Portuguese coast in 2006. It consists of 3 Pelamis units with a combined capacity of 2.25MW installed 5 km off the coast of northern Portugal. The system is presently under repair. However, the technology is promising, and has received several continued support. This include an future expansion to more than 20MW capacity by the Portuguese, a 22.5MW system by Scotland with the first phase in for 2006, and demonstration project sponsored by the Electric Power Research Institute involving five United States sites (Hawaii, Oregon, California, Massachusetts, and Maine). The estimated cost of electricity at these sites range from $0.10/kWh with high wave energy, to about $0.40/kWh with relatively lower wave energy.
Figure F-1: Moored Pelamis device with 4-segment, 3-hinged sections

Note: Top—single unit; bottom—array of multiple units, oriented toward incoming waves

**PowerBuoy Wave Energy Converter**

These devices have a small horizontal dimension (such as a buoy) and utilize the rise and fall of the wave height at a single point for wave energy conversion.

PowerBuoy was developed by Ocean Power Technologies in Pennington, NJ, USA. It consists of a floating buoy inside a fixed cylinder (see Figure F-2). The floating buoy moves up and down driven by the wave motion. The relative motion is used to drive electromechanical or hydraulic energy converters. A 40 kW system was tested offshore from Atlantic City, NJ and in Oahu, Hawaii in 2004-2005. A commercial-scale system of 1.39 MW (with multiple units of PB40) was deployed 3 miles off coast in northern Spain in 2008. A phased installation of array of PB150 (150kW each) system will be conducted in late 2009 at the European Marine energy Centre (EMEC) in Orkney, Scotland to grid connection of commercial array (total system capacity up to 5 MW). The US Navy and DOE also made orders to test and evaluate during 2007-2009. Cost is about $2M for PB150 (2008) and $1.7M for PB40. PB500 (500kW each) is to be the flagship commercial product and costs about $2.5M.
Costs and performance of Pelamis and PowerBuoy systems

Based on a rough estimate, a typical 1.5MW Pelamis ocean wave power generating system composed of two P750 units could have a capacity factor of 40 percent, a capital cost of US$8 million (US$4 million per unit), O&M costs of about US$160,000 per year, an output of about 5.3GWh per year, and a lifetime of 20 years. A typical 1.5 MW PowerBuoy ocean wave power generating system composed of three 500kW PB500 units could have a capacity factor of 50 percent, a capital cost of US$7.5 million (US$2.5 million per unit), O&M costs of about US$200,000 per year, an output of about 6.6GWh per year, and a lifetime of 30 years.

These preliminary data serve as reference for further analysis. Cost estimates will vary depending on actual system design requirements, technology advancement and market demand, and actual wave environment at the installation site (for example, smaller capacity factor for areas with lower wave energy). Note also that these two types of systems are in modular design and the number of basic units (number of PowerBuoy or Pelamis units) can be increased or decreased based on implementation and actual power demand considerations.
References

- RISE Information Portal on Wave Technologies, Research Institute for Sustainable Energy, Australia
- Oscillating Water Column (OWC), Energytech, Australia
- or Oceanlinx Ltd. Australia, [http://www.oceanlinx.com](http://www.oceanlinx.com)
- Pelamis Wave Energy Converter, [http://www.pelamiswave.com](http://www.pelamiswave.com)
Appendix G: Provisions for Grid Stability

Technical measures that may be considered to promote grid stability with increasing fractions of renewables include various options. Here we discuss energy storage, pumped storage, flywheels, interruptible load and demand response contracts, and wind power forecasting. Finally, we discuss the alternative of grid-connected versus off-grid solutions.

G.1 Energy storage

The table below shows energy storage technologies.7

Figure G-1: Energy Storage Technologies

<table>
<thead>
<tr>
<th>Storage Technologies</th>
<th>Main Advantages (Relative)</th>
<th>Disadvantages (Relative)</th>
<th>Power Application</th>
<th>Energy Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumped Storage</td>
<td>High Capacity, Low Cost</td>
<td>Special Site Requirement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAES</td>
<td>High Capacity, Low Cost</td>
<td>Special Site Requirement, Need Gas Fuel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow Batteries: PEB, VRB, ZnBr</td>
<td>High Capacity, Independent Power and Energy Ratings</td>
<td>Low Energy Density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal-Air</td>
<td>Very High Energy Density</td>
<td>Electric Charging is Difficult</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NaS</td>
<td>High Power &amp; Energy Density, High Efficiency</td>
<td>Production Cost, Safety Concerns (addressed in design)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Li-ion</td>
<td>High Power &amp; Energy Density, High Efficiency</td>
<td>High Production Cost, Requires Special Charging Circuit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ni-Cd</td>
<td>High Power &amp; Energy Density, Efficiency</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Other Advanced Batteries</td>
<td>High Power &amp; Energy Density, High Efficiency</td>
<td>High Production Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead-Acid</td>
<td>Low Capital Cost</td>
<td>Limited Cycle Life when Deeply Discharged</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flywheels</td>
<td>High Power</td>
<td>Low Energy density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GMES, DSMES</td>
<td>High Power</td>
<td>Low Energy Density, High Production Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F.C. Capacitors</td>
<td>Long Cycle Life, High Efficiency</td>
<td>Low Energy Density</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There are at least three main flow battery chemistries; Polysulphide Bromide (PSB), Zinc Bromine (ZiBr) and Vanadium Redox Batteries (VRB). The latter has been chosen as an example of this storage type.

Electrical energy storage options such as VRB allow for decoupling of energy storage from instantaneous power requirements (i.e. the energy and power ratings are independent). Most other energy storage technologies require a proportional increase of energy storage capacity in order to deliver a specific power rating. VRB systems are suitable for assisting in the delivery of renewable energy or supplying reactive energy (static VAR compensators are not needed).

The Prudent Energies VRB technology is described as a vanadium-based redox regenerative fuel cell. The electrolyte is pumped from plastic storage tanks (larger tanks equate to larger capacity) across a stack of reversible proton exchange membranes, or PEMs (larger stacks equate to higher instantaneous power output).

The principle of the VRB is shown in more detail in the figure below - it consists of two electrolyte tanks, containing active vanadium species in different oxidation states (positive: V(IV)/V(V) redox couple, negative: V(II)/(III) redox couple). The stack consists of many cells, each of which contains two half-cells that are separated by a membrane. In the half-
cells the electrochemical reactions take place on inert carbon felt polymer composite electrodes from which current may be used to charge or discharge the battery.

**Figure G-3: VRB Technology**

The open circuit cell is from 1.3 to 1.6 V when fully charged and the stack is connected in series to achieve the desired voltage. The relatively fast chemical reactions allow high efficiencies to be achieved without costly catalysts. According to the manufacturer, VRB systems tend to have high efficiency, long cycle life, ease of scalability and negligible environmental impact.

Systems have a “round trip” efficiency of between 65-75 percent. This sacrifice in annual energy output is compensated by the delivery of stable firm capacity. The fluid can be used almost indefinitely and the replaceable cell stack has an estimated life of 10-15 years (some smaller systems have been installed since 1996, larger starting in 2001).

In 2005, the Tomamae “Grid-Coupled Wind Smoothing” VRB went online in Japan. A VRB peak sizing rule of thumb of 20 percent of the peak rated output was used. As a VRB system can deliver 150 percent of rated power for short durations (pulses), a 4MW, 1.5 hour system was chosen for the 32 MW windfarm. As the exact State of Charge (SOC) of the system under load was constantly monitored via the electrolyte levels, this system avoided the potential under- and over-charging issues associated with other battery-based energy systems (which, in turn, informs smaller and more accurate system sizing).

Budgetary pricing ranges from $15.25M US for a 4 MW, 16 MWh system to $44M for a 10MW, 60 MWh system. As additional system time is essentially larger plastic storage tanks of electrolyte solution, greater storage capacity is more affordable than higher power output. Wind resource availability is less of a factor in determining energy storage capacity than is
the grid peak demand profile. As long as grid peak demand statistical duration is less than the storage capacity, firm RE capacity at the power of the VRB system is achieved.

G.2 Pumped storage facilities

Utilizing fresh water, pumped hydro has been in use since the 1890’s in Europe. The charging process can be thought of as a hydro turbine in reverse, and indeed some dams and reservoirs are designed with this capability in mind (their generators become pumps). Seawater has also been used as the lower storage reservoir, as with the 30 MW Yanbaru facility in 1999. About 90 GW, or 3 percent of the global generation capacity, is available through existing pumped storage systems.

Advantages of this method are that it is available at almost any scale that is needed, has a long cycle life and high efficiency (70-85 percent) when utilizing adjustable speed pumps. Disadvantages of this method include the high initial cost and longer development times compared to other battery based systems.

The possibility of applying pumped energy storage facilities to backstop RE generation in Barbados is limited by the size of reservoir that could store sufficient energy to be useful for backstopping RE generation. Given limited land area, the energy density of this option may preclude very large scale installations. However, a simple application of pumped storage by the Barbados Water Authority (BWA) could conceivably permit a significant dispatchable load shed by pumping potable water to elevated storage during off-peak times. This would further improve the efficient operation of BWA’s pumping stations, reducing their overall energy consumption.

G.3 Flywheels

A flywheel is typically a rotating mass which stores potential energy and converts it to electrical energy. Innovations such as carbon fiber, magnetic bearings and near-vacuum chambers have increased the energy, efficiency and lifespan (~20 years) of these units. Advantages are rapid response (once spun up), high cycle life and relatively low maintenance. Smaller systems (2 kW / 6 kWh) have been used in the telecom industry for years and larger systems (1 to 2 MW) have been delivered to utilities throughout the US.

For grid stability, flywheel are an excellent option. For energy storage in the order of hours, cost of a bank of massive flywheels would likely be prohibitive.

Due to its rapid response time and excellent cycle life, this technology is increasingly being examined for renewable energy. A passing cloud or gusting wind can cause fluctuations that range from seconds to minutes, well matched to the fast ramp-rate of flywheels (up to 100 times faster than fossil-fueled generators which can then be brought online if needed).

G.4 Interruptible Load and Demand Response Contracts

Whether its called interruptible load, demand response or peak-shaving, these programs allow contracted participants to receive revenue for turning off loads or starting up their stand-by capacity. For the latter, they earn revenue both for their idle capacity and when they operate their generators.

Industrial consumers in Barbados could be engaged for automated (i.e. dispatchable) load shedding. Similarly, consumers with self generation could also be dispatched with payments for capacity and power generated (saved). Initiating such a demand side management
program would mitigate and stabilize the introduction of intermittent RE generation to the grid.

**G.5 Wind Power Forecasting**

Offshore wind stations may be installed to act as advance predictors for changes in wind energy output. This technique provides sufficient warning to gradually ramp up peaking plants to compensate for variability in wind resource availability. Using wind speed sensors (anemometers) located sufficiently far upwind of the wind farms would provide a very stable contribution for wind energy to the grid.

For more than a few minutes of forecasting there are third party services available. The Alberta Electric System Operator (AESO) in Alberta, Canada recently contracted Denmark-based wind forecasting company WEPROG to provide centralized wind power forecasts for Alberta. The forecasts, ranging from 10 minutes to 144 hours in advance, will be used by various groups within AESO to increase the reliability of the grid. Wind currently represents about 4.4 percent of the 12,763 MW of installed capacity in Alberta, with projects in various phases of completion coming online in the near future.

**G.6 Off-Grid Versus Grid-Connected Systems**

The decision of developing off-grid or grid-connected systems is primarily a commercial one, as opposed to a technical or economic one.

With smaller distributed systems (<50 kW), the decision to go off-grid is a function of the tariff structure. The addition of the requisite battery backup on such small systems is almost never economic compared to direct connection to the grid. In cases where a remote site is located far from the grid and there is a substantial connection cost, battery backed systems may be an economic alternative. However, the connection distance to the island grid in Barbados would not normally justify these extra storage costs. Depending on the development of the Renewable Energy Rider in the longer term, there may or may not be a commercial basis to support off-grid connections in Barbados. Presently, neither the regulated tariff nor the Rider would provide sufficient incentive to justify the added cost of an off-grid battery backed system. If tariff structure reflecting capacity costs is implemented as recommended, off-grid systems may become commercially viable.

Technically, off-grid systems add cost, but do not increase performance. Depending on the valuation of availability, off-grid systems may be commercially justified in the same way that backup generation systems are justified. The current grid availability in Barbados is sufficient for the vast majority of operations, but certain critical applications with severe economic impacts resultant from prolonged outages may support a case for off-grid type solutions—for example, pharmaceutical processes with long process times. In these cases, again there may be a justification for an off-grid battery backed solution, but these represent a very small fraction of the energy consumers on the island.

For larger scale commercial and utility scale systems (>50 kW), the incentive is more driven by grid stability. It does not make any sense for such large systems to exist without grid connection. Rather, the components of the off-grid solution that provide energy storage would be applicable from a grid stabilization perspective.

In terms of technical requirements of the connection, off-grid solutions that may also be connected to the grid must be addressed. The present interconnection requirements
specifically preclude these kinds of connections due to the requirement to prevent energization of the grid during maintenance periods. It would be necessary to provide an islanding function and the corresponding protections, and safety protocols to permit this mode of operation. Islanding is a fairly common operating mode for self-generators and industrial applications where continuous production is required during grid outages. If there is a demand for this operating mode, then the requirements should be appended to the current inter-connection regulations once the Pilot Program for the first implementations is completed.
Appendix H: Potential Energy Efficiency Technologies

In this Appendix, we describe Energy Efficiency technologies, and explain our assumptions and methodology for determining their potential uptake. We present technologies by type:

- **Lighting**—Compact Fluorescent Lamps (CFLs), T8 Fluorescent Lamps with Occupancy Sensor, T5 High Output Fluorescent Lamps, and Street Lighting technologies (Magnetic Induction Street Lighting, LED, and Solar LED)

- **Air Conditioning**—Efficient Window A/C Systems, and Efficient Split A/C Systems

- **Refrigeration**—Efficient Residential Refrigerators, and Efficient Retail Refrigerators (replacement of condensing unit)

- **Mechanical**—Premium Efficiency Motors, Variable Frequency Drives, and Efficient Chillers

- **Other efficient appliances**—LCD Computer Monitors and Power Monitors.

For each EE measure, we provide a table that summarizes its key features, and estimated savings compared to a typical baseline. The key items contained in the tables are as follows:

<table>
<thead>
<tr>
<th>Key features and estimated savings of EE measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Applicable sectors</strong></td>
</tr>
<tr>
<td><strong>Installed capacity (in Watts)</strong></td>
</tr>
<tr>
<td><strong>Baseline replaced</strong></td>
</tr>
<tr>
<td><strong>Unit capital cost (in US$)</strong></td>
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<tr>
<td><strong>O&amp;M costs per year (in US$)</strong></td>
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<tr>
<td><strong>Lifetime (in years)</strong></td>
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<tr>
<td><strong>Energy savings per year (in kWh and in percentage)</strong></td>
</tr>
<tr>
<td><strong>Financial savings per year (in US$)</strong></td>
</tr>
<tr>
<td><strong>Payback (in years)</strong></td>
</tr>
<tr>
<td><strong>NPV over lifetime (in US$)</strong></td>
</tr>
<tr>
<td><strong>Savings cost (in US$ per kWh)</strong></td>
</tr>
</tbody>
</table>
H.1 Lighting measures

Below we describe CFLs, T8 Fluorescent Lamps with Occupancy Sensor, T5 High Output Fluorescent Lamps and Led Street Lighting.

Compact Fluorescent Lamps (CFLs)

CFLs are available at many local hardware and lighting suppliers in Barbados. They replace conventional incandescent lamps, compared to which they offer the following advantages: higher efficiency (more power converted to light, and less to heat—approximately 20 percent against 10 percent); higher efficacy (3-5 more lumen per Watt, allowing to achieve same or higher luminosity with a lower bulb power); longer lifetime (up to 10-20 times more). The cost however is significantly higher then a typical incandescent bulb. Ensuring quality CFLs are purchased and installed is critical—some lower-quality products are cheaper, but are likely to fail prematurely. Many of the higher quality bulbs come with a warranty in which the bulbs will be replaced if there is a failure during the warranty period.

The most common application of CFLs is in the residential sector—most households in Barbados still use incandescent lamps. Most businesses already use fluorescent lamps, (although often of the older and less efficient T12 type), but some still have incandescent lighting, and could benefit from the installation of CFLs too. The table below summarizes key features and estimated savings of a typical CFL retrofit—a 15W CFL replacing a 60W incandescent lamp.

<table>
<thead>
<tr>
<th>Compact Fluorescent Lamps (CFLs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable sectors</td>
</tr>
<tr>
<td>Installed capacity (in Watts)</td>
</tr>
<tr>
<td>Baseline replaced</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
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<tr>
<td>Lifetime (in years)</td>
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<tr>
<td>Energy savings per year (in kWh and in percentage)</td>
</tr>
<tr>
<td>Financial savings per year (in US$)</td>
</tr>
<tr>
<td>Payback (in years)</td>
</tr>
<tr>
<td>NPV over lifetime (in US$)</td>
</tr>
<tr>
<td>Savings cost (in US$ per kWh)</td>
</tr>
</tbody>
</table>
T8 Fluorescent Lamps

Four-foot fluorescent fixtures are common in the commercial, industrial, and public sectors in Barbados. Many of these fixtures contain two 40W T12 lamps with magnetic ballasts,\textsuperscript{9} which are fluorescent lights of an older and less efficient kind. A typical EE measure consists of retrofitting these fixtures by replacing the 40W T12 lamps with 32W T8 lamps and the magnetic ballast with an electronic ballast. These lamps consume less energy thanks to a lower installed capacity, but generate a greater amount of lumens. A good range of T8 lamps is available, such as the energy-saving T8-F25 type (25W per lamp before considering the ballast).

When retrofitting 40W T12 lamps, we recommend installing 25W T8 lamps with an electronic ballast. The 25W T8 lamps produce a similar lumen output to that of a 40W T12 lamp resulting in a minimal change in light levels. An electronic ballast further reduces energy consumption by about 5 percent compared to a magnetic ballast, with minimal changes to light levels. We recommend high-efficiency rapid or program start electronic ballasts for any retrofit. It is important to purchase a quality ballast as a poor ballast can result in premature lamp failure. Lamp life is about 30,000 hours—this results in lower maintenance with fewer lamps to be changed.

We also recommend installing T8 lamps in association with occupancy sensors—we describe occupancy sensors below, and provide a common summary table for these two EE measures used together.

Occupancy Sensors

Occupancy sensors automatically turn off lights when they detect a given space is not occupied (and can also automatically turn lights on when they detect it is occupied). Although energy savings from occupancy sensors depend on the actual behavior of occupants, this measure often delivers good energy savings—we estimate about 20 percent based on our experience. We recommend dual occupancy sensors—that is, sensors that detect occupancy through passive infrared heat (heat emitted by all living things) as well as movement.

The table below summarizes key features and estimated savings of a lighting retrofit consisting of replacing two T12 lamps with two T8 lamps and an Occupancy Sensor.

<table>
<thead>
<tr>
<th>T8 Fluorescent Lamps with Occupancy Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Applicable sectors</strong></td>
</tr>
<tr>
<td><strong>Installed capacity (in Watts)</strong></td>
</tr>
<tr>
<td><strong>Baseline replaced</strong></td>
</tr>
</tbody>
</table>

\textsuperscript{9} The “T” used for non-residential CFLs is a measure of the lamp’s tubular diameter, in eights of inches (1 inch = 2.5 centimeters).

\textsuperscript{10} A ballast is a device that limits the consumption of current in a circuit, regulating/optimizing the flow. Electronic ballasts change the frequency of power to a much higher one, increasing lamp efficacy (capacity to produce a desired effect, in this case lumen, measure of perceived light), doing so more efficiently than magnetic ballasts, and can operate more than one lamp (in parallel better than in series given one’s failure won’t affect the others).
Unit capital cost (in US$) | 150 (including two lamps, a ballast and an Occupancy Sensor)
---|---
O&M costs per year (in US$) | None
Lifetime (in years) | 18.8 (30,000 hours, 6.4 hours per day—instead of 8 per day thanks to 20 percent extra savings from the Occupancy Sensor—and 250 days per year)
Energy savings per year (in kWh and in percentage) | 116kWh with two lamps, overall 60 percent savings over baseline (51 percent savings in capacity plus 20 percent further savings from the Occupancy Sensor)
Financial savings per year (in US$) | 39
Payback (in years) | 3.9
NPV over lifetime (in US$) | 289
Savings cost (in US$ per kWh) | 0.12

**T5 High Output Fluorescent Lamps**

High-bay fixtures are common throughout the industrial sector, and can also be found in some commercial and public buildings. Most of these high-bay fixtures use a conventional 400W metal halide lamp. These fixtures can be replaced by a 6-lamp T5 High Output (HO) 6x54W fixture. The entire fixture consumes about 25 percent less power than the 400W metal halide. This measure involves a complete fixture replacement unlike the other measures where there is a simple lamp replacement.

Another benefit of the retrofit is higher lamp lifetime—T5HO fixtures have a 20,000 hour lamp lifetime, which is up to 10 times more than conventional lamps. This reduces the frequency of re-lamping the fixtures, an activity that is expensive in high-bay areas. Also, T5HO fixtures turn on instantly and provide a consistent light level and color rendering index. The linear fluorescent lighting provides more uniform lighting distribution, which improves occupants’ overall comfort. Additional savings can be achieved with the installation of multilevel switches, which allow reducing the number of operating lamps of a fixture at any given time.

The table below summarizes key features and estimated savings of replacing a metal halide lamp with a six-lamp T5HO fixture.

| T5 High Output Fluorescent Lamps |
|---|---|
| **Applicable sectors** | Mostly Industrial. Also Commercial, and Public |
| **Installed capacity (in Watts)** | 6x54Watts (352 Watts actual power thanks electronic ballast) |
| **Baseline replaced** | 400 Watt metal halide lamp (458 Watts actual power due to magnetic ballast) |

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11 High Bay Light Fixtures are suitable for indoor applications where ceiling height exceeds 15 feet, and are ideal for general purpose lighting in areas such as warehouse facilities, assembly areas, gyms, hangars, transportation garages, loading and staging areas.
### Street Lighting

**Visual perception of light.** It is important to understand the night vision as it is the main factor for the cause of accidents that occur under low visibility. The eye has two visual receptors, rods and cones. Cones functions primarily under Photopic (daylight) vision. Rods are the main active visual receptor under Scotopic (night) vision. Photopic vision exhibits low light sensitivity, high acuity and color vision. Scotopic vision is characterized by high light sensitivity, poor acuity and no color vision. Scotopic vision is sensitive in blue color range. The high pressure sodium street lights are not human eye “friendly”; these lamps produce “yellow–orange” tones. The scotopic response is lowest at these wavelengths. The light source that has a broad spectral output with large amount of blue output such as induction, ceramic metal halide, or LED, can reduce energy use while improving perceptions of visibility, safety and security.\(^{13}\)

**Option 1: Magnetic Induction Street Lighting.** The 30W Spectrally Enhanced Magnetic Induction lighting technology is proposed as a replacement of the existing 50W high pressure sodium street lighting fixtures in Barbados. The expected lamp life of magnetic induction lamp is 20 years. They are approximately 50 percent more efficient than the conventional high pressure sodium lamp. The magnetic induction lamp provides better visually effective lumens resulting in higher quality light that will match the current lighting level of conventional high pressure street lighting. Maintenance is significantly reduced—a typical baseline conventional high pressure sodium lamp would require 4-5 times as many replacements compared to a magnetic induction lamp. We estimate a US$35 maintenance savings per lamp per year.\(^{14}\)

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\(^{12}\) BC Hydro - QA STANDARD Technology: Effective Measure Life Effective November 1, 2005

\(^{13}\) LRC “Proven Method available to significantly reduce energy consumption in street lighting”.

\(^{14}\) LED Roadway Lighting Limited, Nova Scotia, Canada.
Spectrally enhanced magnetic induction technology has instant start capabilities, no flickering, and uses the program start electronic ballast. The color rendering index (CRI) of high pressure sodium lamp is 20. Magnetic induction lamps have a CRI of 80. The magnetic induction lamp provides higher quality of the light with better reproduction of colors of visual environment.

The table below summarizes key features and estimated savings of a magnetic induction street light replacing an existing conventional high pressure sodium street lamp.

<table>
<thead>
<tr>
<th>Magnetic Induction Street Lighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable sectors</td>
</tr>
<tr>
<td>Installed capacity (in Watts)</td>
</tr>
<tr>
<td>Baseline replaced</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
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<tr>
<td>Energy savings per year (in kWh and in percentage)</td>
</tr>
<tr>
<td>Financial savings per year (in US$)</td>
</tr>
<tr>
<td>Payback (in years)</td>
</tr>
<tr>
<td>NPV over lifetime (in US$)</td>
</tr>
<tr>
<td>Savings cost (in US$ per kWh)</td>
</tr>
</tbody>
</table>

**Option 2: LED Street Lighting.** The majority of the street lighting in Barbados consist of 50W high-pressure sodium fixtures. New Light-Emitting Diode (LED) Street Lighting technologies are available with an expected design life of 20 years. They are approximately 40 percent more efficient than typical high-pressure sodium fixtures. Although they do not provide as many lumens as the high-pressure sodium fixtures do, the LED lights provide more direct lighting resulting in less light pollution. They also offer substantial savings in maintenance costs—a typical baseline high-pressure sodium incandescent fixture requires relamping at least four times before a LED lamp does. We estimate a US$35 maintenance savings per lamp per year.\(^{15}\)

The table below summarizes key features and estimated savings of a LED street light replacing a conventional street lamp.

\(^{15}\) LED Roadway Lighting Limited, Nova Scotia, Canada.
Option 3: LED Street Lighting with solar panels (New installation). Electric Street Lights are significant consumers of energy. Today’s solar street lighting technology has evolved; it converts the sun’s energy into electricity and stores it to provide illumination from dusk to dawn. The system includes the power generator (panels), storage (battery) and energy management system (controller) as well as the LED light and pole.

An evaluation of Solar driven LED lights was conducted for new installations in Barbados. A major benefit available in new installations is the elimination of cable runs between lights and tie-ins to the grid. Without these savings the upfront capital cost for solar street lighting systems could not be justifiable given pricing available today. Some of the benefits of solar lights are listed below:

- Easy installation, no trenching, no wiring from and to the grid
- Immune to power outages
- Stand alone, not connected to the grid
- Vandal and theft-resistant components and hardware
- No cuts through the existing roads, sidewalks or landscaping
- Low maintenance costs
- No energy cost
- Better color rendition and nighttime visibility
- Lower light pollution

<table>
<thead>
<tr>
<th>LED Street Lighting</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable sectors</td>
<td>Public</td>
</tr>
<tr>
<td>Installed capacity (in Watts)</td>
<td>35 Watts</td>
</tr>
<tr>
<td>Baseline replaced</td>
<td>High-Pressure Sodium 50 Watt lamp</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
<td>1,000</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
<td>(35)—savings over baseline costs</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
<td>20 (12 hours per day, 365 days per year)</td>
</tr>
<tr>
<td>Energy savings per year (in kWh and in percentage)</td>
<td>98.6kWh (39 percent savings over baseline)</td>
</tr>
<tr>
<td>Financial savings per year (in US$)</td>
<td>26 (61 including O&amp;M savings)</td>
</tr>
<tr>
<td>Payback (in years)</td>
<td>16.3</td>
</tr>
<tr>
<td>NPV over lifetime (in US$)</td>
<td>(240)</td>
</tr>
<tr>
<td>Savings cost (in US$ per kWh)</td>
<td>0.53</td>
</tr>
</tbody>
</table>
- No Warm-Up or Cold start problems
- Solar panels have a lifetime of 20 years

Cost saving assumption for trenching, cabling and backfill costs: US$50/m.

Based on 30m between fixtures, there will be a cost saving of about US$1,500 per fixture by avoiding trenching, cabling, and backfilling. This cost is based on an assumption that a significant portion of trenching would need to be done through limestone which is very near to the surface in many parts of the island.

The table below summarizes key features and estimated savings of a Solar LED street light for new installation.

<table>
<thead>
<tr>
<th>Solar LED Street Lighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable sectors</td>
</tr>
<tr>
<td>Installed capacity (in Watts)</td>
</tr>
<tr>
<td>Baseline</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
</tr>
<tr>
<td>Energy savings per year (in kWh and in percentage)</td>
</tr>
<tr>
<td>Financial savings per year (in US$)</td>
</tr>
<tr>
<td>Payback (in years)</td>
</tr>
<tr>
<td>NPV over lifetime (in US$)</td>
</tr>
<tr>
<td>Savings cost (in US$ per kWh)</td>
</tr>
</tbody>
</table>

### H.2 Air conditioning measures

Below we describe Efficient Window A/C systems and Efficient Split A/C Systems.

**Efficient Window Air Conditioning Systems**

According to a Demand-Side Management Study commissioned by BL&P, residential air conditioners account for about 44 percent of electricity use in high-income households, 5 percent in middle-income households, and 2 percent in low-income households. This data is from 2000—A/C penetration has increased in low- and middle-income households since then, based on anecdotal evidence. Most A/C systems in low- and middle-income households are window units, although such units may also be found in the commercial,

---

industrial, and public sectors. New efficient window A/C units can achieve savings of over 30 percent. The table below summarizes key features and estimated savings of an efficient window A/C unit replacing a conventional one.

**Efficient Window A/C Systems**

<table>
<thead>
<tr>
<th>Applicable sectors</th>
<th>Mostly Residential. Also Commercial, Industrial, and Public</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed capacity (in Watts)</td>
<td>1.0kW</td>
</tr>
<tr>
<td>Baseline replaced</td>
<td>1.5kW</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
<td>500</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
<td>None—same as for baseline</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
<td>15 (4 hours per day, 365 days per year)</td>
</tr>
<tr>
<td>Energy savings per year (in kWh and in percentage)</td>
<td>730kWh (33 percent over baseline)</td>
</tr>
<tr>
<td>Financial savings per year (in US$)</td>
<td>221</td>
</tr>
<tr>
<td>Payback (in years)</td>
<td>2.3</td>
</tr>
<tr>
<td>NPV over lifetime (in US$)</td>
<td>1,677</td>
</tr>
<tr>
<td>Savings cost (in US$ per kWh)</td>
<td>0.07</td>
</tr>
</tbody>
</table>

**Efficient Split Air Conditioning Systems**

Split A/C systems are commonly used in Barbados—mostly in commercial, industrial, and public premises, but also in households. In addition to retrofitting older systems with new more efficient units, use of electricity by split systems can be reduced through better design and installation practices. Based on our preliminary site visits, many existing units are installed to serve a single space—this is an inefficient configuration for a building with multiple rooms of similar footage. New direct digital controls allow serving multiple rooms’ cooling coils with a single outdoor unit. Some of the new EE split A/C systems use variable frequency driver (VFD) technology—described below—which may further decrease the electrical usage.

The table below summarizes key features and estimated savings of a retrofit involving the replacement of an old split A/C system with a new one.

**Efficient Split A/C Systems**

<table>
<thead>
<tr>
<th>Applicable sectors</th>
<th>Mostly Commercial, Industrial, and Public. Also Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed capacity (in Watts)</td>
<td>1.8kW</td>
</tr>
<tr>
<td>Baseline replaced</td>
<td>3.0kW</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
<td>2,000</td>
</tr>
</tbody>
</table>
### H.3 Refrigeration measures

Below we describe Efficient Residential Refrigerators, and Efficient Retail Refrigerators (for these, we consider the replacement of the condensing unit only).

**Efficient Residential Refrigerators**

According to the Demand Sided Management report of 2000, refrigerators represent over 40 percent of households’ electricity bill. Older refrigerators are inefficient compared to new equipment, and many old units also do not have proper insulation for Barbados’ warm climate. The frequency of power supply is also a problem—North American refrigerators, installed on a 50hz power supply, are inefficient and consume more energy than advertised. We recommend importing European refrigerators rated for 50hz operation.

The 2000 DSM study’s analysis of electrical data for residential refrigerators revealed that most units operate at an average power factor of 0.6 which was verified by our own study—this is far lower than the 0.93 power factor of electricity distribution in Barbados. Capacitors can address this problem—their installation would have no effect on customers’ bills (since the Domestic Service Tariff includes no demand charge component). However, capacitors would create an aggregate benefit to the system considering the residential sector as a whole, reducing the kVA produced to meet the demand. The table below summarizes key features and estimated savings of a replacement of an old residential refrigerator with a new efficient one.

---

**Notes:**


18 The power factor is the ratio between real power (capacity of a circuit to perform work in a determined time) and apparent power (depends on circuit’s current/voltage, can be greater than real power). Capacitors are devices that can store energy in the electric field formed between two conductors (or plates) holding charges of equal magnitude but opposite polarity. Capacitors can be used for energy storage, as temporary batteries, or in EE applications to correct the power factor in machinery receiving electricity from grid or engines, adjusting the load to have the power factor as close to 1 as possible (that is, have real power equal apparent power).
### Efficient Residential Refrigerators

<table>
<thead>
<tr>
<th>Applicable sectors</th>
<th>Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed capacity (in Watts)</td>
<td>105 Watt average power draw</td>
</tr>
<tr>
<td>Baseline replaced</td>
<td>160 Watt average power draw</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
<td>1,000</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
<td>None—same as for baseline</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
<td>12 years</td>
</tr>
<tr>
<td>Energy savings per year (in kWh and in percentage)</td>
<td>481.8kWh (34 percent over baseline)</td>
</tr>
<tr>
<td>Financial savings per year (in US$)</td>
<td>146</td>
</tr>
<tr>
<td>Payback (in years)</td>
<td>6.9</td>
</tr>
<tr>
<td>NPV over lifetime (in US$)</td>
<td>281</td>
</tr>
<tr>
<td>Savings cost (in US$ per kWh)</td>
<td>0.25</td>
</tr>
</tbody>
</table>

### Efficient Retail Refrigerators (Replacement of the Condensing Unit)

Commercial refrigerators and freezers are used primarily in the retail sector by convenience stores, supermarkets, and restaurants for storing or merchandising refrigerated or frozen products such as cold drinks, ice cube bags and frozen foods. However, these types of refrigerators are also sometimes found in industrial or public premises.

Self-contained commercial refrigerators and freezers often include exterior condensing units providing the cooling. Electrically powered refrigerated cases have shelves or drawers with one, two or three opaque or transparent doors, and—like those found in supermarkets—may have one or more interior lights to illuminate the contents. Various retrofits in these commercial refrigerators are possible, with savings up to 40 percent, including:

- **Efficient lighting**: interior illuminating lights can be retrofitted with T8 fluorescent lights with electronic ballasts, compact fluorescent lamps, LED lights, and programmable timers and controls that cycle lights and temperature as needed
- **Efficient compressors**: commercial refrigerators and freezers use reciprocating compressors. These can be retrofitted with energy-efficient scroll or linear compressors
- **High-efficiency small motors**: fans can be retrofitted with energy efficient permanent magnet motors—electronically-commutated motors (ECM) with efficient fan blades run cooler
- **Cabinet design improvements**: these include better face frame and door gaskets, thicker insulations using foam-in-place insulation rather than mineral fiber insulations,
and better condensate drain design, including traps to prevent air infiltration and reduce energy consumption

- **Replacement of the condensing unit only**—this achieves savings on the cooling performance while limiting costs of replacement.

The table below summarizes key features and estimated savings of retrofitting a condensing unit in a retail refrigerator with an efficient one.

<table>
<thead>
<tr>
<th>Efficient Retail Refrigerators (Replacement of Condensing Unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Applicable sectors</strong></td>
</tr>
<tr>
<td><strong>Installed capacity (in Watts)</strong></td>
</tr>
<tr>
<td><strong>Baseline replaced</strong></td>
</tr>
<tr>
<td><strong>Unit capital cost (in US$)</strong></td>
</tr>
<tr>
<td><strong>O&amp;M costs per year (in US$)</strong></td>
</tr>
<tr>
<td><strong>Lifetime (in years)</strong></td>
</tr>
<tr>
<td><strong>Energy savings per year (in kWh and in percentage)</strong></td>
</tr>
<tr>
<td><strong>Financial savings per year (in US$)</strong></td>
</tr>
<tr>
<td><strong>Payback (in years)</strong></td>
</tr>
<tr>
<td><strong>NPV over lifetime (in US$)</strong></td>
</tr>
<tr>
<td><strong>Savings cost (in US$ per kWh)</strong></td>
</tr>
</tbody>
</table>

**H.4 Mechanical measures**

Below we describe Premium Efficiency Motors, Variable Frequency Drives, and Efficient Chillers (we present chillers with mechanical measures although they also achieve refrigeration however most this size either serve large commercial buildings or industrial processes).

**Premium Efficiency Motors**

Industrial facilities use a wide range of motors that have long operating hours—some even operate continuously. Electric motor systems consume large amounts of electrical energy, and represent significant opportunities for energy savings. Energy represents more than 97 percent of total motor operating costs over the motor’s lifetime. However, the purchase of a new motor often tends to be driven by price, not by the amount of energy it will consume. Even a small improvement in efficiency may result in significant energy and cost savings. In cases where motors have failed and been rewound and reinstalled the savings can be significant as every time a motor is rewound it looses some of its efficiency.
Payback depends on the hours a motor is running—assuming a 10HP motor operates for 12 hours a day throughout the year, the payback can be between 4 and 5 years, but it can drop to 2-3 years were the motor to operate continuously.

The table below summarizes key features and estimated savings of a retrofit involving the installation of premium efficiency motors.

### Premium Efficiency Motors

<table>
<thead>
<tr>
<th>Applicable sectors</th>
<th>Mostly Industrial. Also Commercial and Public Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed capacity (in Watts)</td>
<td>11.2kW rated power, 80 percent motor loading, 91 percent efficiency (9.85kW actual power)</td>
</tr>
<tr>
<td>Baseline replaced</td>
<td>11.2kW rated power, 80 percent motor loading, 87 percent efficiency (10.35 kW actual power)</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
<td>1,500</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
<td>None—same as for baseline</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
<td>20 years (operating 50 percent of time throughout the year)</td>
</tr>
<tr>
<td>Energy savings per year (in kWh and in percentage)</td>
<td>2,191kWh (5 percent over baseline)</td>
</tr>
<tr>
<td>Financial savings per year (in US$)</td>
<td>728</td>
</tr>
<tr>
<td>Payback (in years)</td>
<td>2.1</td>
</tr>
<tr>
<td>NPV over lifetime (in US$)</td>
<td>6,938</td>
</tr>
<tr>
<td>Savings cost (in US$ per kWh)</td>
<td>0.06</td>
</tr>
</tbody>
</table>

### Variable Frequency Drives

A variable frequency drive adjusts motor speed to meet actual demand, resulting in energy savings when reducing motor speed for periods of lower demand. Most process motors operate at a constant speed irrespective of the process load requirement. In water pumping, for example, a conventional motor runs at constant speed throughout its operating time, irrespective of peak water demand. There is a cubic relationship between the power consumed by a motor and its speed. For example, a 50 percent reduction in speed will result in 87.5 percent savings in electrical energy consumption.

Savings from variable frequency drives must be analyzed on a case by case basis. Typically, in most cases where the load can be varied, paybacks will range from 5 to 10 years. The table below summarizes key features and estimated savings of installing a variable frequency drive to a motor.

### Variable Frequency Drives

<table>
<thead>
<tr>
<th>Applicable sectors</th>
<th>Industrial, as well as Commercial and Public Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed capacity (in Watts)</td>
<td>11.2kW rated power, 80 percent motor loading, 91 percent efficiency</td>
</tr>
</tbody>
</table>
(7.18kW actual power), average operating speed 90 percent

<table>
<thead>
<tr>
<th>Baseline replaced</th>
<th>11.2kW rated power, 80 percent motor loading, 91 percent efficiency (9.85 kW actual power), average operating speed 100 percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit capital cost (in US$)</td>
<td>7,000</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
<td>60 (due to installation of the VFD)</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
<td>10 years¹⁹ (operating 50 percent of time throughout the year)</td>
</tr>
<tr>
<td>Energy savings per year (in kWh and in percentage)</td>
<td>11,687kWh (27 percent over baseline)</td>
</tr>
<tr>
<td>Financial savings per year (in US$)</td>
<td>3,885</td>
</tr>
<tr>
<td>Payback (in years)</td>
<td>1.8</td>
</tr>
<tr>
<td>NPV over lifetime (in US$)</td>
<td>21,545</td>
</tr>
<tr>
<td>Savings cost (in US$ per kWh)</td>
<td>0.09</td>
</tr>
</tbody>
</table>

**Efficient Chillers**

Based on our preliminary review, several chillers currently in use operate at constant speed with standard efficiency compressors—they operate at a lower Coefficient of Performance (COP)²⁰ value. Conventional chillers should be retrofitted with modern energy efficient chillers that typically operate at a minimum COP. In addition, modern chillers incorporate compressors with variable frequency drive technology (VFD). Chillers with VFD technology and direct digital control can reduce the electrical consumption by chilled systems by up to 30 percent.

The table below describes key features and estimated savings of retrofitting a chiller.

<table>
<thead>
<tr>
<th>Efficient Chillers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Applicable sectors</strong></td>
</tr>
<tr>
<td><strong>Installed capacity (in Watts)</strong></td>
</tr>
<tr>
<td><strong>Baseline replaced</strong></td>
</tr>
<tr>
<td><strong>Unit capital cost (in US$)</strong></td>
</tr>
<tr>
<td><strong>O&amp;M costs per year (in US$)</strong></td>
</tr>
<tr>
<td><strong>Lifetime (in years)</strong></td>
</tr>
<tr>
<td><strong>Energy savings per year (in kWh)</strong></td>
</tr>
</tbody>
</table>

¹⁹ BChydro - QA STANDARD Technology: Effective Measure Life Effective November 1, 2005

²⁰ The Coefficient of Performance is the efficiency ratio of the amount of heating or cooling provided by a heating or cooling unit to the energy consumed by the system.
and in percentage)

| Financial savings per year (in US$) | 7,790 |
| Payback (in years) | 5.1 |
| NPV over lifetime (in US$) | 51,623 |
| Savings cost (in US$ per kWh) | 0.15 |

### H.5 Other efficient appliances

Below we present Computer LCD Monitors and Power Monitors.

#### Computer LCD Monitors

Desktop Cathode Ray Tube (CRT) computer monitors can be retrofitted with energy efficient liquid crystal display (LCD) monitors. 19” 40W LCD computer monitors can replace conventional 120W CRT monitors of the same size, with savings in installed capacity and consumption of 67 percent. The market is slowly shifting towards LCD monitors as CRT monitors are becoming less prevalent in stores and in the near future there may be no other option but to purchase an LCD monitor when purchasing a new monitor.

The table below summarizes key features and estimated savings of a retrofit using a LCD monitor of this type.

<table>
<thead>
<tr>
<th>LCD Computer Monitors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Applicable sectors</strong></td>
</tr>
<tr>
<td><strong>Installed capacity (in Watts)</strong></td>
</tr>
<tr>
<td><strong>Baseline replaced</strong></td>
</tr>
<tr>
<td><strong>Unit capital cost (in US$)</strong></td>
</tr>
<tr>
<td><strong>O&amp;M costs per year (in US$)</strong></td>
</tr>
<tr>
<td><strong>Lifetime (in years)</strong></td>
</tr>
<tr>
<td><strong>Energy savings per year (in kWh and in percentage)</strong></td>
</tr>
<tr>
<td><strong>Financial savings per year (in US$)</strong></td>
</tr>
<tr>
<td><strong>Payback (in years)</strong></td>
</tr>
<tr>
<td><strong>NPV over lifetime (in US$)</strong></td>
</tr>
<tr>
<td><strong>Savings cost (in US$ per kWh)</strong></td>
</tr>
</tbody>
</table>
Power Monitors

Power monitors represent an opportunity for education and awareness of energy conservation. These devices are intended for the residential sector. The power monitor is simply a device that is connected to the house’s electricity meter and has a wireless display monitor that indicates the current and historical power consumption. The device can be used to determine the power consumption of various appliances throughout the house and is meant to make the occupants aware of their effect on their energy use thus resulting in a change of habits to a more energy conscious homeowner. Studies\(^\text{21}\) have shown a change of habits such as turning lights off and unplugging equipment can result in a 10 percent reduction in energy use.

The table below summarizes key features and estimated savings of a using a power monitor of this type.

<table>
<thead>
<tr>
<th>Power Monitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable sectors</td>
</tr>
<tr>
<td>Installed capacity (in Watts)</td>
</tr>
<tr>
<td>Baseline replaced</td>
</tr>
<tr>
<td>Unit capital cost (in US$)</td>
</tr>
<tr>
<td>O&amp;M costs per year (in US$)</td>
</tr>
<tr>
<td>Lifetime (in years)</td>
</tr>
<tr>
<td>Energy savings per year (in kWh and in percentage)</td>
</tr>
<tr>
<td>Financial savings per year (in US$)</td>
</tr>
<tr>
<td>Payback (in years)</td>
</tr>
<tr>
<td>NPV over lifetime (in US$)</td>
</tr>
<tr>
<td>Savings cost (in US$ per kWh)</td>
</tr>
</tbody>
</table>

H.6 Methodology in determining potential energy efficiency technologies and current uptake

Our review of the different sectors and potential energy efficiency opportunities involved a review of existing documentation, interviews with local residents, and walk-through energy audits of various facilities. Our experienced energy auditors reviewed all of this information and used it as the basis of our assumptions for identifying key energy efficiency technologies for Barbados, and their current level of penetration.

One of the primary sources of information was BL&P’s Demand Side Management (DSM) Study22 of 2000. This study provided an analysis and breakdown of energy use by customer types. Although this study is 10 years old, it is the latest comprehensive study available, and—based on our direct observations, which revealed no significant energy efficiency upgrades since then—we estimated that the general breakdown of energy use remained fairly close to the estimate contained in the study.

We also reviewed previous energy audits done for public sector buildings. These included walk-through energy audits for the Government Headquarters building, the Sherbourne Conference Centre, the Sir Frank Walcott Building, the Psychiatric Hospital, and the Ministry of Agriculture Headquarters building. In addition, we reviewed a detailed energy audit for the University of West Indies buildings.

We gathered information on the residential sector through a walk-through audit of a couple of homes, and interviews with staff from the Stantec office in Barbados regarding their own homes as well as others they visited. We tested a number of refrigerators using a power meter to determine the potential savings.

We also conducted walk-through energy audits to assess the potential for EE and RE technologies in Barbados. Buildings we visited included commercial office buildings, retail malls, industrial plants, food processing facilities, beverage manufacturers, electrical contractors, and solar water heater companies. Appendix N contains a list of our site visits.

Finally, we integrated these dedicated site visits with observations of any building we visited while in Barbados—for example, the BCIC office, TMR Sales, Solar Dynamics, the SSA office, and hotels (Blue Horizon, Savannah, South Beach Resort, and Accra).

H.7 Assumptions for potential uptake of energy efficiency technologies

We evaluated the potential impact of energy efficiency technologies in Barbados, exploring the potential uptake of each as compared to an estimated current one. We identified the key sectors where each technology could be implemented. Although technologies could be implemented in any sector, we did not consider application in a sector when it would be negligible (for example, commercial companies could in some cases benefit from premium efficiency motors, but these would only represent a small portion of overall energy use in the sector, compared to the industrial sector where energy from motors is a significant portion of energy use).

The table below shows, for all technologies we analyzed:

---

Applicable sectors (residential, commercial, and industrial)

A breakdown of the energy use per sector, based on BL&P’s Demand Side Management (DSM) Study\(^{23}\) of 2000. In this study, the sectors were broken down into three main categories of Residential, Commercial (including office style public buildings and tourism) and Industrial (including public services buildings). They were then further broken down into end-use categories such as lighting, cooling, and refrigeration.

The percentage savings of each technology over its typical baseline, as shown in tables per EE technology above.

Estimated current uptake, based on the field visits made by Stantec in September and October 2009 to a small sample of residential, commercial, industrial, and public premises.

Estimated potential under the SEF program over a 20-year period, to determine the reduction in energy use for each sector, based on Stantec’s experience in the energy efficiency market. It is rare to see any EE measure achieve 100 percent uptake in the market—we mostly assumed a maximum penetration of 70 percent.

Estimated savings potential in electricity consumption for each sector.

<table>
<thead>
<tr>
<th></th>
<th>CFLs</th>
<th>Power Monitors</th>
<th>Premium Efficiency Motors</th>
<th>Efficient Window A/C Systems</th>
<th>Variable Frequency Drives</th>
<th>Efficient Split A/C Systems</th>
<th>T8 Fluorescent Lamps with Occupancy Sensor</th>
<th>Efficient Chillers</th>
<th>T5 High Output Fluorescent Lamps</th>
<th>Efficient Residential Refrigerators (Condensing Unit)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Residential</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current share of total sector energy use</td>
<td>19%</td>
<td>74%*</td>
<td>-</td>
<td>6%</td>
<td>-</td>
<td>1%</td>
<td>-</td>
<td>-</td>
<td></td>
<td>45%</td>
<td></td>
</tr>
<tr>
<td>Technology Energy Saving Potential</td>
<td>75%</td>
<td>10%</td>
<td>-</td>
<td>33%</td>
<td>-</td>
<td>38%</td>
<td>-</td>
<td>-</td>
<td></td>
<td>34%</td>
<td></td>
</tr>
<tr>
<td>Estimated Current uptake</td>
<td>5%</td>
<td>0%</td>
<td>-</td>
<td>5%</td>
<td>-</td>
<td>5%</td>
<td>-</td>
<td>-</td>
<td></td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Estimated potential uptake</td>
<td>70%</td>
<td>30%</td>
<td>-</td>
<td>50%</td>
<td>-</td>
<td>50%</td>
<td>-</td>
<td>-</td>
<td></td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td>Estimated Savings Potential</td>
<td>9.4%</td>
<td>2.2%</td>
<td>-</td>
<td>0.9%</td>
<td>-</td>
<td>0.2%</td>
<td>-</td>
<td>-</td>
<td></td>
<td>11.2%</td>
<td>23.9%</td>
</tr>
</tbody>
</table>

Source: Stantec and Castalia estimates.

Note: * For Power Monitors the potential savings applies to 100% the consumption less the energy saved by the other EE measures.
### Commercial

<table>
<thead>
<tr>
<th></th>
<th>CFLs</th>
<th>Power Monitors</th>
<th>Premium Efficiency Motors</th>
<th>Efficient Window A/C Systems</th>
<th>Variable Frequency Drives</th>
<th>Efficient Split A/C Systems</th>
<th>T8 Fluorescent Lamps with Occupancy Sensor</th>
<th>Efficient Chillers</th>
<th>T5 High Output Fluorescent Lamps</th>
<th>LCD Computer Monitors</th>
<th>Efficient Residential Refrigerators</th>
<th>Efficient Retail Refrigerators (Condensing Unit)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current share of total sector energy use</strong></td>
<td>3%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>50%</td>
<td>18%</td>
<td>-</td>
<td>-</td>
<td>0.5%</td>
<td>-</td>
<td>13%</td>
<td>-</td>
</tr>
<tr>
<td><strong>Technology Energy Saving Potential</strong></td>
<td>75%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>38%</td>
<td>60%</td>
<td>-</td>
<td>-</td>
<td>67%</td>
<td>-</td>
<td>15%</td>
<td>-</td>
</tr>
<tr>
<td><strong>Estimated Current uptake</strong></td>
<td>5%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5%</td>
<td>10%</td>
<td>-</td>
<td>-</td>
<td>30%</td>
<td>-</td>
<td>0%</td>
<td>-</td>
</tr>
<tr>
<td><strong>Estimated potential uptake</strong></td>
<td>70%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>70%</td>
<td>70%</td>
<td>-</td>
<td>-</td>
<td>100%</td>
<td>-</td>
<td>70%</td>
<td>-</td>
</tr>
<tr>
<td><strong>Estimated Savings Potential</strong></td>
<td>1.5%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>12.5%</td>
<td>6.7%</td>
<td>-</td>
<td>-</td>
<td>0.3%</td>
<td>-</td>
<td>1.3%</td>
<td>22.4%</td>
</tr>
</tbody>
</table>

Source: Stantec and Castalia estimates.
<table>
<thead>
<tr>
<th>Technology</th>
<th>Current Share of Total Sector Energy Use</th>
<th>Technology Energy Saving Potential</th>
<th>Estimated Current Uptake</th>
<th>Estimated Potential Uptake</th>
<th>Estimated Savings Potential</th>
<th>Total Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFLs</td>
<td>0.3% - 41%** 6% 0.9% 19.1% 1.7% - - -</td>
<td>75% 25% 38% 60% 40% 23% - - -</td>
<td>5% 0% 5% 10% 5% 0% - - -</td>
<td>70% 50% 70% 50% 50% - - -</td>
<td>0.1% 1% 5.1% 1.4% 0.3% 3.5% 0.2% - - -</td>
<td>6.0% 1.3% 0.2% 0.5% 0.9% 8.0% 4.2% 0.6% 0.03% 0.2% 6.5% 0.8% 0.4% 21.9%</td>
</tr>
<tr>
<td>Power Monitors</td>
<td>- - 41%** 6% 41%** 9% 1.7% - - -</td>
<td>5% 38% 60% 40% 23% - - -</td>
<td>0% - - - - - -</td>
<td>0% - - - - - -</td>
<td>11.8%</td>
<td></td>
</tr>
<tr>
<td>Premium Efficiency Motors</td>
<td>- - 41%** 6% 41%** 9% 1.7% - - -</td>
<td>5% 38% 60% 40% 23% - - -</td>
<td>0% - - - - - -</td>
<td>0% - - - - - -</td>
<td>11.8%</td>
<td></td>
</tr>
<tr>
<td>Efficient Window A/C Systems</td>
<td>- - 41%** 6% 41%** 9% 1.7% - - -</td>
<td>5% 38% 60% 40% 23% - - -</td>
<td>0% - - - - - -</td>
<td>0% - - - - - -</td>
<td>11.8%</td>
<td></td>
</tr>
<tr>
<td>Variable Frequency Drives</td>
<td>- - 41%** 6% 41%** 9% 1.7% - - -</td>
<td>5% 38% 60% 40% 23% - - -</td>
<td>0% - - - - - -</td>
<td>0% - - - - - -</td>
<td>11.8%</td>
<td></td>
</tr>
<tr>
<td>Efficient Split A/C Systems</td>
<td>- - 41%** 6% 41%** 9% 1.7% - - -</td>
<td>5% 38% 60% 40% 23% - - -</td>
<td>0% - - - - - -</td>
<td>0% - - - - - -</td>
<td>11.8%</td>
<td></td>
</tr>
<tr>
<td>T8 Fluorescent Lamps with Occupancy Sensor</td>
<td>- - 41%** 6% 41%** 9% 1.7% - - -</td>
<td>5% 38% 60% 40% 23% - - -</td>
<td>0% - - - - - -</td>
<td>0% - - - - - -</td>
<td>11.8%</td>
<td></td>
</tr>
<tr>
<td>Efficient Chillers</td>
<td>- - 41%** 6% 41%** 9% 1.7% - - -</td>
<td>5% 38% 60% 40% 23% - - -</td>
<td>0% - - - - - -</td>
<td>0% - - - - - -</td>
<td>11.8%</td>
<td></td>
</tr>
<tr>
<td>T5 High Output Fluorescent Lamps</td>
<td>- - 41%** 6% 41%** 9% 1.7% - - -</td>
<td>5% 38% 60% 40% 23% - - -</td>
<td>0% - - - - - -</td>
<td>0% - - - - - -</td>
<td>11.8%</td>
<td></td>
</tr>
<tr>
<td>LCD Computer Monitors</td>
<td>- - 41%** 6% 41%** 9% 1.7% - - -</td>
<td>5% 38% 60% 40% 23% - - -</td>
<td>0% - - - - - -</td>
<td>0% - - - - - -</td>
<td>11.8%</td>
<td></td>
</tr>
<tr>
<td>Efficient Residential Refrigerators</td>
<td>- - 41%** 6% 41%** 9% 1.7% - - -</td>
<td>5% 38% 60% 40% 23% - - -</td>
<td>0% - - - - - -</td>
<td>0% - - - - - -</td>
<td>11.8%</td>
<td></td>
</tr>
<tr>
<td>Efficient Retail Refrigerators (Condensing Unit)</td>
<td>- - 41%** 6% 41%** 9% 1.7% - - -</td>
<td>5% 38% 60% 40% 23% - - -</td>
<td>0% - - - - - -</td>
<td>0% - - - - - -</td>
<td>11.8%</td>
<td></td>
</tr>
<tr>
<td>Street Lights</td>
<td>- - 41%** 6% 41%** 9% 1.7% - - -</td>
<td>5% 38% 60% 40% 23% - - -</td>
<td>0% - - - - - -</td>
<td>0% - - - - - -</td>
<td>11.8%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100%***</td>
<td>48%</td>
<td>0%</td>
<td>100%</td>
<td>11.8%</td>
<td></td>
</tr>
</tbody>
</table>

Source: Stantec and Castalia estimates.

Note: ** Both technologies can be applied to the same portion of the sector and are often done in conjunction with one another resulting in cumulative savings.

*** 100% of street lighting energy use
To estimate potential uptake of the technologies in each applicable sector, we made the following considerations based on our research and experience:

- **CFLs.** The opportunity for CFLs spans all sectors, as incandescent lights can also be found throughout all sectors. Within the next 20 years, an estimated (maximum) 70 percent uptake is reasonable. CFLs have already been introduced into the market, and thanks to increasing awareness and education of their benefits, we expect this to be an achievable target. However, unless the import of incandescent light bulbs is banned, some consumers will still use them.

- **Power Monitors.** Power monitors do not save any energy themselves, but rely upon people to use the device to educate themselves on how to save energy. We expected their uptake to be lower than other technologies—about 30 percent uptake, based on their promotion through the SEF Pilot Program and the possible spread to other consumers.

- **Magnetic Induction Street Lights.** Currently this technology is not used on any street lights in Barbados. However, given its high viability and low cost, we expect a 100 percent uptake for this technology over 20 years. Street lighting is part of public sector use, and tariffs are currently subsidized by the government—the public sector should lead by example and mandate a change over the next 20 years, and could at the same time reduce the level of cross-subsidy to this use.

- **Premium Efficiency Motors.** Based on our experience, penetration of EE technologies in the industrial sector can sometimes be difficult—many companies require short paybacks (1-2 years), and do not wish to stop the production process to replace equipment to save energy unless savings are significant. Uptake of EE technologies in the industrial sector is anticipated to be slower than in others (industrial users tend to select lowest-cost solutions despite higher-cost ones may yield more savings in the longer term). We estimated uptake of premium efficiency motors in the industrial sector to reach 50 percent in the next 20 years, as during that time many motors will require replacement and many companies will see the benefit of not replacing like for like.

- **Efficient Window A/C Systems.** Window A/C systems are primarily found in the residential sector. A policy for allowing efficient units to be sold will make the biggest contribution to the penetration rate. Until a similar policy is in place, there will still be some inefficient units installed. We assumed a (maximum) 70 percent uptake in the next 20 years.

- **Variable Frequency Drives.** The considerations made for premium efficiency motors in the industrial sector also apply to VFDs. Although these technologies offer higher potential savings than premium efficiency motors, many consumers are not aware of the opportunity or understand the benefit of the technology and where it can be installed. Through education and awareness campaigns and incentive programs (grants and loans) the use of VFDs can grow. Overall, we assumed a 50 percent uptake.

- **Efficient Split A/C Systems.** A/C split systems are primarily found in the commercial sector, with some units installed in the residential sector. Just like the window A/C units, we expect policies for promoting efficient split A/C units to
result in a 70 percent uptake in the next 20 years. Unless there is a mandatory requirement for energy efficient A/C systems the inefficient systems will remain. With a standard for energy efficient A/C units in place a significant change will be seen as the majority of the units will reach the end of their lifecycle and require replacement, however by the time a policy is in place there will be a number of inefficient units remaining

- **T8 Fluorescent Lamps with occupancy sensors.** Fluorescent tube lighting is very common in both the commercial and industrial sector, especially in offices. With appropriate education and awareness combined with grant and loan incentives, this technology should easily reach a penetration rate of 70 percent. As long as the same light types are available, at least some customers will still not replace them in spite of higher consumption and costs

- **Efficient chillers.** Although there are some chillers in some of the larger commercial buildings, energy consumption is small in comparison to cooling in the industrial sector (primarily process cooling). As with other industrial industry technologies, although the retrofit can save a lot of energy it will still meet some resistance as a retrofit means interruption of the production process. The best time is when the equipment has reached the end of its life cycle—which within the next 20 years will occur for many chillers. Therefore, we assumed a 50 percent uptake

- **T5 High Output Fluorescent Lamps.** High output T5 fixtures are a good retrofit for high bay fixtures, and would primarily be implemented in the industrial sector. This is an expensive technology, and may be subject to some resistance—however, energy savings and improved lighting potential will still entice some businesses to implement it. We assumed a 50 percent uptake

- **LCD Computer Monitors.** LCD computer monitors are used in all sectors, but computer monitors make up only a small portion of the energy consumption in each sector. For the residential and industrial sectors it is considered to be less than 0.1 percent—we did not include these sectors in projections. In the commercial sector the energy consumption is higher due to offices with many computers within small areas. CRT monitors are naturally phasing themselves out as most suppliers do not even sell them. We anticipate that over the next 20 years 100 percent of CRT monitors will be replaced with LCD monitors

- **Efficient Residential Refrigerators.** We expect a 80 percent uptake of efficient refrigerators in the next 20 years. This uptake is higher than that of any other residential technology because during this period most refrigerators will require replacement, and with an EE standard in place options for inefficient refrigerators will be limited. Also, as it is the most significant electrical appliance in a home, consumers will tend to purchase mostly efficient refrigerators

- **Efficient Retail Refrigerators (Condensing Unit).** We expect a 70 percent uptake for this technology, based on the high replacement rate of condensing units.

We used estimates of technologies’ uptake to calculate the percentage reduction that all technologies could have on each sector by 2029. The overall savings based on the
assumptions above result in a percentage reduction in electricity consumption for each sector of:

- 23.9 percent for the residential sector
- 22.4 percent for the commercial sector
- 13.3 percent for the industrial sector.

Then, we calculated the annual incremental rate that the overall savings percentage above would imply by 2029, based on a geometric average over a 20-year period.

Then, we calculated the historical average annual reduction in electricity consumption in the various sectors over the past 20 years. We applied this historical average to projected consumption during the next twenty years to determine consumption under the base case scenario.

Finally, we applied the estimated additional annual reduction in electricity consumption to determine the ‘high energy efficiency scenario’. The overall result is a 19.3 percent reduction in electricity consumption compared to the ‘business as usual’ scenario for 2029.
Appendix I: Site Visits for Energy Efficiency (September—October 2009)

### Building Walk-Through Assessments

<table>
<thead>
<tr>
<th>Premise</th>
<th>Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stantec Office</td>
<td>Commercial Office Building</td>
</tr>
<tr>
<td>Biscuit Manufacturing</td>
<td>Industrial (bakeries &amp; confectionary)</td>
</tr>
<tr>
<td>Ms. Archer's House</td>
<td>Residential (private household)</td>
</tr>
<tr>
<td>Mall Internationale</td>
<td>Commercial (retail mall)</td>
</tr>
<tr>
<td>Rum Distillery</td>
<td>Industrial</td>
</tr>
<tr>
<td>FTC Building</td>
<td>Commercial (office building)</td>
</tr>
<tr>
<td>Banks Brewery</td>
<td>Industrial</td>
</tr>
<tr>
<td>Jordan's Supermarket</td>
<td>Commercial (retail store)</td>
</tr>
<tr>
<td>Pinehill Dairy</td>
<td>Industrial</td>
</tr>
<tr>
<td>Andrew's Sugar Cane Factory</td>
<td>Industrial</td>
</tr>
<tr>
<td>Barbados Lumber Co.</td>
<td>Commercial</td>
</tr>
<tr>
<td>University of West Indies</td>
<td>Education</td>
</tr>
</tbody>
</table>

### Interviews with Equipment Suppliers

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>SunPower</td>
<td>Solar Water Heating (Sales &amp; Installation)</td>
</tr>
<tr>
<td>Solar Dynamics</td>
<td>Solar Water Heating (Sales &amp; Installation)</td>
</tr>
<tr>
<td>Rtec</td>
<td>Mechanical Contractor</td>
</tr>
<tr>
<td>Solar Energy Innovation Inc.</td>
<td>Electrical and PV systems Contractors</td>
</tr>
<tr>
<td>Williams Electrical</td>
<td>Electrical and PV systems Contractors</td>
</tr>
<tr>
<td>TMR Sales</td>
<td>Mechanical Contractor</td>
</tr>
<tr>
<td>Caribbean Security Systems (CSS)</td>
<td>Direct Digital Controls Contractors</td>
</tr>
</tbody>
</table>
Appendix J: Capabilities of Local and Regional Energy Services Companies (ESCOs)

ESCOs from Barbados and the Caribbean region have adequate capability and experience to conduct EE audits and small-scale or product-specific retrofits. However, these companies are limited in the type and scale of work they can perform. There is not yet sufficient appetite amongst regional financial institutions to support market growth, and regional ESCOs do not yet have sufficient size to take on larger retrofit assignments. In the sections below we first discuss the capabilities of regional ESCOs, then we examine the limits of these capabilities.

J.1 Proven capability to implement small-scale assessments and conduct product-specific retrofits

ESCOs in Barbados and the broader Caribbean are capable providers of small-scale EE and RE assessments and product-specific energy retrofits, as well as broader retrofits on a limited basis. Small-scale energy efficiency audits and renewable energy assessments are a core competency of Caribbean and Barbadian ESCOs. For example, Williams Evergreen and Clarke Energy Associates—small ESCOs local to Barbados—leverage the expertise of highly qualified but small staff to assess the feasibility of limited RE solutions for small and medium-sized projects. For example, Williams Evergreen recently helped the Pinehill Dairy install a Smartcool energy efficiency system to reduce consumption related to refrigeration.

Many local and regional companies also specialize in providing product-specific retrofits. For instance, Solar Dynamics and Sun Power manufacture and install solar hot water heaters. These companies drive demand both by demonstrating the benefits of their products and by helping to provide financing. They differ from energy efficiency auditors because they implement and finance retrofits, and also because the information they provide is tailored to sell specific products (rather than to maximize overall cost savings).

Some larger ESCOs are able to provide combined audit/retrofit services on an Energy Performance Contract (EPC) basis. Companies such as Caribbean ESCO and ECO-TEC harness a broader set of skills, allowing them to conduct feasibility studies and then implement EE retrofits based upon the results of those studies. Caribbean ESCO performs all of these functions in-house, while ECO-TEC focuses on management, sales and assessment, but subcontracts retrofits to other firms.

J.2 ESCOs’ capabilities are limited by their small scale and by availability of financing

The key limitations of ESCOs in Barbados and the Caribbean region are poor availability of financing and lack of scale. ESCOs in developed countries are able to concentrate on technical and energy-saving aspects of efforts since a mature financing sector usually takes care of the investment. ESCOs in developing countries, however, have to make significant efforts to secure funding for projects. Caribbean ESCOs will sometimes co-finance their energy efficiency improvements. This limits regional ESCOs, forcing them to use their capital to drive demand for projects rather than to expand their staff or grow their capabilities.
The lack of financing also contributes to regional ESCOs’ other major problem: they are not large enough. Even though the ESCOs currently operating in the Caribbean may be technically capable, they do not have the capacity to handle large projects. A public sector energy audits program consisting of a number of buildings may be difficult for one company to complete within a short time frame. Partially for this reason, the Government of Barbados has selected multiple companies to assess facilities during previous energy audits.
Appendix K: Energy Audit Guidelines (October 2009)

Guidelines for Energy Audits
Residential Sector

1. General Description of the Activity

This activity consists of a walk-through energy audit of the mechanical, electrical, lighting and building envelope systems for the 25 residential facilities listed in [TBD].

2. Energy Audit Scope of Services

The Contractor shall review each residence’s utility consumption, identifying current annual utility usage (kWh), and annual costs (BBD); and calculate average monthly usage and costs.

The Contractor shall conduct a site review. The site review shall cover the following four areas:

1. **Equipment/appliances.** Identify energy consuming equipment/appliances (such as refrigerators, freezers, domestic water heater, stove, dishwasher, washing machine, dryer, television and air conditioning), and list equipment/appliances installed indicating Brand, Model & Serial Number, and Age of Equipment. Estimate power consumption of each device. Make field measurements where required to verify operating parameters.
2. **Lighting.** Identify lighting installed, and indicate type, quantity, wattage, and time of use.
3. **Building characteristics.** Review characteristics of the building envelope and interior environmental conditions (e.g. Temperature and Humidity).
4. **Energy usage patterns.** Interview the home owner (or resident, for rented facilities) to determine typical use of equipment, typical operating hours of equipment and lighting, and age of equipment.

The Contractor shall summarize the findings of the energy audit in a short report, using the attached template.

The report shall include: (i) an identification of the residence address and resident (indicating if owner or not); (ii) the review of each residence’s utility consumption; (iii) the site review, covering the four areas described above; and (iv) a final section listing the energy saving recommendations with estimated cost and anticipated payback range.

The Consultant shall submit one (1) electronic copy of a draft report for review and comment (in Adobe Acrobat PDF format). Based on comments received, the Contractor shall then submit two (2) copies of the report, plus one electronic copy (in Adobe Acrobat PDF format on compact disk).
# Energy Audit Report Template—Residential Sector

## Residence details

<table>
<thead>
<tr>
<th>Address:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Resident (indicate if owner):</td>
<td></td>
</tr>
</tbody>
</table>

## Review of utility consumption

<table>
<thead>
<tr>
<th>Utility usage (kWh), annual:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility Account Number:</td>
<td></td>
</tr>
<tr>
<td>Costs (BBD), annual:</td>
<td></td>
</tr>
<tr>
<td>Tariff Rate:</td>
<td></td>
</tr>
</tbody>
</table>

## Site review

### 1. Equipment/appliances:

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Brand</th>
<th>Model/Serial No.</th>
<th>Age (yrs)</th>
<th>Capacity (W)</th>
<th>Estimated Annual Consumption (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2. Lighting:

<table>
<thead>
<tr>
<th>Room</th>
<th>Type</th>
<th>Quantity</th>
<th>Wattage</th>
<th>Duration (hrs/day)</th>
<th>Estimated Annual Consumption (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

### 3. Building characteristics:


### 4. Energy usage patterns:


## Energy saving recommendations
Guidelines for Energy Audits
Commercial, Industrial and Government Sector

1. General Description of the Activity

The activity consists of a detailed energy audit of the mechanical, electrical, lighting and building envelope systems for the facilities listed in [TBD].

2. Energy Audit Scope of Services

The Consultant shall become familiar with the functional and operational characteristics of the facility, and make recommendations that are sensitive to the facility’s functional and operational requirements.

This shall be done in four steps, described in greater detail below:

- Conduct a utility analysis
- Conduct onsite data collection
- Analysis & development of energy efficiency recommendations
- Prepare an energy audit report.

Conduct a utility analysis. The Consultant shall conduct a detailed utility analysis for all purchased and self-generated energy. The utility analysis shall be conducted as a desktop activity prior to the site visit. The Consultant shall request all relevant documentation, and gather any missing information during the site visit.

The utility analysis shall cover the following:

1. Identification of historical use patterns over a minimum period of 3 years
2. Identification of energy types (electricity from grid, solar energy, natural gas, etc.) used and quantity
3. Patterns of use by energy type
4. Identification of utility rate structure in BBD
5. Normalization of utility data over a three (3) year period for use as a baseline
6. Utility energy use analysis by building type and size (Building Energy Performance Index—total annual energy usage measured against the size of the facility).

Following the site visit the Consultant shall prepare a breakdown (energy balance) of the total annual energy use into end-use components (Cooling, Fans, Lighting, Motors, etc.).

Conduct onsite data collection. The Consultant shall conduct a site visit to the facility. During the site visit, the Consultant shall:

1. Interview key facility personnel to establish operating characteristics of the facility, operating and maintenance procedures, unusual operating constraints, and anticipated future expansions or changes to the facility
2. Inspect and observe the facility, energy use flows and its operations, including architectural, lighting and power, mechanical, and process energy systems
3. Review all available documentation, including all architectural, mechanical and electrical drawings
4. Make field measurements where required to verify operating parameters.

**Analysis & Development of energy efficiency recommendations.** The Consultant shall develop the concept of energy efficiency improvements related to, but not restricted to: lighting; power factor; motors; ventilating and air conditioning; cooling; process cooling; building envelope; control systems; alternate energy sources; load sharing and load shedding.

For lighting recommendations, the Consultant shall compare existing installed luminaries to proposed luminaries to ensure that proposed options maintain adequate light levels and uniformity for a facility of this type and usage.

The Consultant shall categorize and list all energy conservation measures or alternative energy sources considered, tabulate those that were considered but are not viable, and give reasons for their non-viability.

The Consultant shall evaluate in detail those energy-saving measures or alternative energy sources which, taken together, result in an overall payback of better than ten (10) years. The Consultant shall ensure that design and project management costs are capitalized in the payback analysis.

The Consultant shall evaluate in detail those energy-saving measures or alternative energy sources that have a payback superior to the ten (10) year threshold, but that have the potential for significant energy savings or greenhouse gas reductions. The Consultant shall ensure that design and project management costs are capitalized in the payback and financial analysis.

For each recommended measure, the Consultant will provide:

1. A description of the recommended measure that will achieve verifiable energy savings, replace conventional energy sources with renewable or alternative energy sources, or achieve verifiable greenhouse gas emissions reductions. To include scope of work for the retrofit.
2. Specific reference to any innovative measure
3. Project cost estimate with itemized design, project management, materials/equipment (including quantities), labor, commissioning, training, and VAT costs
4. Projected annual utility savings with itemized power, natural gas, and water/sewer savings
5. Projected avoided greenhouse gas emissions with itemized power, natural gas, and water/sewer savings
6. Description of other benefits/impacts
7. Maintenance costs
8. Projected annual cost savings with itemized power, natural gas, and water/sewer savings
9. Projected payback, both simple and with interest at the prevailing rate
10. Life cycle cost/benefit analysis
11. Recommended measurement and verification method(s) that will be required to
determine the actual effectiveness of the recommended measures.

**Prepare an energy audit report.** The Consultant shall prepare an energy audit report that
shall include the following:

1. Executive Summary (compiled by completed the summary table attached)
2. Introduction
3. Glossary of Terms
4. Utility analysis
5. Description of Existing Systems
6. Energy Conservation Measures (estimated energy and cost savings, and associated
   implementation cost)
7. Conclusion
8. Appendices (reference data for analysis presented in the report).

The Executive Summary shall be compiled using the two tables attached:

- Table 1 shall summarize facility details, utility analysis data, rates used in savings
  analysis, and energy end-use breakdown
- Table 2 shall summarize recommended energy conservation measures.

The Consultant shall submit one electronic copy of a draft report for review and comment
(in Adobe Acrobat PDF format).

Based on comments received, the Consultant shall submit five (5) copies of the final report
plus one electronic copy (in Adobe Acrobat PDF format on compact disk).
Table 1.
Facility details | Utility analysis data
--- | ---
Name of Facility: | Annual Electricity Usage (kWh/yr):
Address: | Annual Electricity Cost (BBD/yr):
Owner/Managing Company: | Annual Natural Gas Usage (GJ/yr):
Total floor area of Facility (m²) | Annual Natural Gas Cost (BBD/yr):

Rates used in savings analysis | Annual Energy Usage (Other Fuels):
--- | ---
Electricity (BBD/kWh) | Annual Energy Cost (BBD/yr):
Natural Gas (BBD/GJ) | Total Energy Usage (ekWh):
Other Fuels | Building Energy Performance Index (ekWh/m²):
Water/sewer | Building Energy Performance Index Benchmark (ekWh/m²):
Escalation Rate (%) | Capacity for Self Generation (kVA):
Discount Rate (%) | Specific Energy Intensity (production/eKWh): (Industrial/Manufacturing Only)
Specific Energy Intensity Benchmark (production/eKWh): (Industrial/Manufacturing Only)

Energy end-use breakdown

Table 2.
Summary of Energy Conservation Measures

<table>
<thead>
<tr>
<th>Measure Number</th>
<th>Description</th>
<th>Annual Savings</th>
<th>Emissions Reduction (Equ. CO₂ tonnes/yr)</th>
<th>Total Project Cost (BBD)</th>
<th>Simple Payback (Years)</th>
<th>Effective Measure Life (Years)</th>
<th>Net Present Value (BBD)</th>
<th>Internal Rate of Return (%)</th>
<th>Discounted Payback (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Electricity (kWh)</td>
<td>Natural Gas (GJ)</td>
<td>Other Fuels</td>
<td>Sub-Total (BBD)</td>
<td>Maintenance (BBD)</td>
<td>Total Savings (BBD)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix L: Smart Fund Design

The Government intends to establish a Smart Fund (the ‘Fund’) to promote EE measures and RE projects. This Smart Fund will provide grants and subsidized loans to promote increased use of EE and RE. The Government is negotiating a US$10 million Investment Loan with the IDB; the proceeds of this loan will be used to capitalize the Fund.

Based on our analysis, and taking into consideration the Government’s comments and preferences since our initial workshop in November 2009 and as ultimately defined by the Ministry of Finance, Infrastructure, Telecommunications, and Energy (MFIE) in May 2010, we recommend establishing five separate components for the Smart Fund:

- **Pilot Consumer Finance Facility (Hire Purchase)**—US$0.5 million (revolving loans)
- **Compact Fluorescent Lamps Promotion**—US$0.5 million (grants)
- **Air Conditioner (A/C) Rebate Trade-In Program**—US$1.5 million (grants)
- **Energy Efficiency Retrofit and Renewable Energy Finance Facility**—US$6.5 million (revolving loans)
- **Discretionary Facility**—US$1.0 million (grant and Fund administrative costs).

With these five components, the Fund would focus mostly on businesses, and also on households, and would promote economically viable EE and RE technologies requiring additional financial support to increase their use in Barbados. We describe these recommendations in greater detail later in this Appendix:

- Section L.1 presents guidance we received from the Government that is incorporated into the design of the Smart Fund
- Section L.2 explains how we have chosen the recommended financial instruments, and then illustrates how these instruments would work
- Section L.3 describes which types of customers should be eligible for support from the Smart Fund
- Section L.4 presents recommendations for administering the Smart Fund.

A successful Smart Fund will catalyze the spread of EE and RE technologies in Barbados. On the supply side, it will lead retailers to procure and sell economically viable EE (and RE) technologies that are available in limited supplies in Barbados. The availability and initial subsidized cost of equipment (along with a well-coordinated communications strategy), will encourage households and businesses to buy and install economically viable EE and RE technologies. In this way, the Smart Fund will contribute to shifting the market (suppliers, contractors, households and businesses) toward greater use of EE and RE technologies.

**L.1 Government Guidance for Designing the Smart Fund**

The Government has provided guidance and preferences regarding the objectives, design and attributes of the Smart Fund. We have incorporated this guidance in our recommendations.

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24 Email communication by the SEF Project Manager, 17 May 2010.
The Government has three high-level objectives for the Smart Fund:

- Reduce energy costs
- Improve energy security, and
- Enhance environmental sustainability.

Beyond its high-level objectives, the Government has also informed us that the Smart Fund’s design should take into account the following preferences:

- Most of the funds available should be used to establish loans with below-market rates, therefore allowing the Smart Fund to operate mostly as a self-sustaining (or ‘revolving’) loan facility
- The cost of any audits could be covered (at least in part) by loans
- Size of loans should be limited to ensure that small and medium businesses of the industrial and commercial sectors benefit from the money
- Money for purchasing and distributing free CFLs should be limited, giving preference to direct regulation (phase-out plan for incandescent lights, as discussed in section 6 of the Report) for promoting efficient lighting
- The hire purchase consumer finance facility should be a pilot program initially, with a view to testing how it works and, if successful, replicating it under a possible second phase of the Investment Loan that MFIE might consider establishing
- A small part of the Smart Fund must be set aside for grants for use by the Government for activities such as awareness programs
- The loan from the IDB should be repaid directly through the general budget (not from revenues generated by the Smart Fund).

L.2 Recommended Financial Instruments

The financial instruments we propose for the Smart Fund are based on our analysis and initial suggestions to the Government, on the guidance received from the Government, and on the following four criteria we view as critical to the Smart Fund’s success:

1. **Choose instruments that will eliminate market barriers**—As explained in Sections 4 and 5 of the Report, many EE and RE measures are economically viable in Barbados, meaning that more households and businesses should already be purchasing and using these measures. Two key barriers to increasing the use of these items are limited access to capital and limited and uncompetitive supply of these economically viable technologies. Financial instruments should be chosen that will help to overcome these specific barriers

2. **Leverage existing retail loan providers**—Since the Government does not want the Smart Fund to provide retail loans to households and businesses, the revolving portion of the Fund must leverage existing retail loan providers, in particular the Enterprise Growth Fund Limited (EGFL). Existing facilities have proven products, established distribution channels, and therefore a higher likelihood of success

3. **Choose instruments that are simple**—Simple instruments work best, both for managing the Fund, and for the households and business that would use the funding
provided by the Fund. Simple instruments are also the most transparent—their functioning is easily understood by the public. Any subsidies that the Fund would provide need to be explicit, and the public must know that it is the Fund that provides them. Simple instruments also leverage the sales and marketing skills of existing specialized entities, as well as their retail capabilities.

4. **Choose instruments that allow preserving the Fund's resources**—the Fund should carefully balance grant and loan products to allow operating mostly as a revolving facility based on own resources deriving from loans.

In accordance with these criteria we recommend that the Smart Fund use the following five financial instruments:

- **Pilot Consumer Finance Facility (Hire Purchase).** A US$0.5 million pilot revolving fund that provides loans at below-market rates to a retailer25 for supporting a low-interest hire-purchase scheme for EE equipment. Given that the facility in its pilot phase will be limited in size, and only involve one participating retailer, RE systems will be unlikely to be financed initially—although this will be possible if the facility is subsequently replicated. This facility builds on a mechanism that is familiar in Barbados; it leverages existing retail, marketing and sales capabilities; and it can preserve resources, operating as a revolving fund.

- **Compact Fluorescent Lamps Promotion.** A US$0.5 million grant facility for purchasing and distributing free Compact Fluorescent Lamps (CFLs) in exchange for incandescent bulbs. This scheme will build demand for CFLs in Barbados while simultaneously helping retailers to expand their supplies to more economic levels (which should lead to lower prices and better product availability).

- **Air Conditioner (A/C) Rebate Trade-In Program.** A US$1.5 million rebate facility to cover a portion of the price of new efficient air conditioning units. This scheme will make energy efficient air conditioners available at a 50 percent discount if customers exchange inefficient air conditioners (a “cash for clunkers” program)—this level of rebate will be necessary to allow this facility to work. Similar to the CFL program, this scheme will increase demand for energy efficient air conditioners while simultaneously helping retailers to expand supplies to more economic levels.

- **Energy Efficiency Retrofit and Renewable Energy Finance Facility.** A US$6.5 million revolving fund that provides loans at below-market rates (‘soft loans’) for EE and RE to small-medium businesses in the industrial and commercial sectors (including hotels). This scheme will reduce the cost of EE retrofits and RE systems using low-interest loans. This scheme will leverage the expertise of the Enterprise Growth Fund Limited (EGFL), taking advantage of its expertise in providing credit to small businesses.

- **Discretionary Facility.** A US$1.0 million discretionary facility for MFIE to use as needed, including to cover management fees for grant facilities (A/C trade-in and CFLs facilities), replicate activities of the SEF Pilot Program (grants for PVs and

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25 ‘Retailers’ refers to stores that buy goods from manufacturers or importers and then sell those goods to end-users.
CFLs), and develop awareness campaigns. Simple, discretionary subsidies can achieve quick results (even on a one-time or temporary basis).

Each of these recommendations, and the analysis behind them, is described in more detail below.

L.2.1 Pilot Consumer Finance Facility ( Hire Purchase), US$0.5 million

A low-interest hire purchase scheme would increase demand for economically viable equipment by overcoming the barrier posed by lack of finance. The increase in demand would stimulate supply, therefore reducing prices (through increases in volume and competition in the supply chain) and so lower prices while expanding availability of the equipment. The proposed mechanism is for the Smart Fund to support a low-interest hire purchase scheme by providing below-market financing to a participating retailer, on a pilot basis.

While in our initial Fund design this was the largest of the Smart Fund’s facilities, the Government has indicated its preference for trying it on a pilot basis before considering potential replication on a larger scale. This could happen through a second phase of the Investment Loan with the IDB that the Government may consider. The limited amount allocated for the pilot phase suggests selecting only one retailer—if replicated, more retailers could pre-qualify for participation in the scheme.

Overview of hire purchase in Barbados

In Barbados, the Hire Purchase, Credit-Sale and Hire-Control Act (Chapter 328A) defines hire purchase as:

An agreement for the bailment of goods under which the bailee may buy the good or under which the property in the goods will or may pass to the bailee.

In Barbados, hire purchase schemes are typically used for items that have a cost of at least BB$1,000, such as large furniture items, white goods, and solar water heaters. 26 Hire purchase schemes typically account for over 50 percent of all sales by major retailers. 27 The decision to use a hire purchase scheme is made at the point of purchase. If a customer wishes to pay for an item using hire purchase, the retailer first runs an employment and credit check to ensure that the customer is capable of making monthly payments. Consumers with excellent qualifying credit do not need to make a down payment on the purchased item, but many consumers will be required to make a 10 or 20 percent down payment. The interest rate charged for hire-purchase financing is typically 1.75 percent per month (which equates to an effective annual interest rate of 23.1 percent). 28 Payments are typically spread over an 18 to 24 month period. 29

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26 Conversation with a Dacosta Mannings representative on 27 January 2010. Dacosta Mannings indicated that hire purchase schemes may be offered for goods as cheap as BB$600, with the decision of whether or not to offer hire purchase schemes made solely at Dacosta Mannings’ discretion.

27 Conversation with a Courts representative on 29 January 2010.

28 All annual interest rates presented in this document are compounded annual interest rates. For example, 1.75 percent monthly interest compounded over 12 months is equal to a 23.1 percent annual interest rate, according to the following formula: 23.1% = (1 + 1.75%)^12 – 1.

29 This period may be as short as six months or as long as 30 months, depending on the price of the item.
Dacosta Mannings, a major retailer in Barbados, uses a slightly different hire purchase scheme for the sale of solar water heaters. When selling solar water heaters, it charges customers a lower-than-typical interest rate—1.25 percent monthly interest (corresponding to a 16 percent annual interest). Dacosta Mannings can do this for two reasons:

- It does not incur any carrying cost on these items because it does not hold them in inventory
- It recovers a portion of the interest that it forgoes through an up-front commission that it receives from the solar water heater installers. This commission is equal to 10 percent of the price of installation.

Courts, another major retailer operating in Barbados, also sells solar water heaters through a hire-purchase scheme where it operates solely as the financier and receives a commission from the supplier. Courts, however, does not discount its hire purchase interest rates below its typical interest rates.

We recommend the Smart Fund provide below-market financing for a hire-purchase scheme on a pilot basis

The Smart Fund should aim to test its ability to improve the terms on which hire purchase financing is offered for efficient equipment. The Smart Fund will offer low-interest loans that a retailer may access if, in turn, it agrees to lend to customers through a hire purchase scheme at below-market terms that will be pre-specified. We expect that these better terms on the hire-purchase schemes will increase the volume of efficient equipment that a retailer buys and keeps in stock.

This should lead to positive outcomes for all three parties—the Government, the participating retailer, and consumers. The Government will achieve its policy objectives by increasing uptake of efficient equipment through below-market loans to support the subsidized hire-purchase scheme. The retailer will profit from the lower cost of capital provided by the Smart Fund allowing it to offer better terms, and so increase sales. Consumers will benefit from the savings they receive in the form of a lower interest rate, as well as the lower energy costs the equipment will provide.

Financial design of the low interest hire-purchase facility

The key to this scheme is reducing the cost of borrowing for consumers. The Smart Fund will offer a retailer a loan at a below-market rate (we recommend a five percent effective annual interest rate). A retailer can use the loan for a hire-purchase scheme with pre-specified terms (interest rates of up to eight percent and tenors of four years). An annual interest rate of eight percent is well below the typical interest rate charged for hire-purchase in Barbados.30

Another key to the subsidized hire purchase scheme is ensuring an adequate interest margin for a retailer. Retailers offer hire purchase financing at an interest rate that is higher than their own cost of capital. They use this margin between the rate they charge and the rate they pay to cover the costs of bad debts and administrating the hire purchase programs. If the subsidized

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30 Consumers in Barbados typically can choose between consumer loans and standard hire-purchase schemes if they wish to finance their retail purchases. Hire purchase is described in detail above. Consumer loans are offered by financial institutions such as banks and credit unions. They typically carry an interest rate between 17 and 20 percent and a tenor of three to four years. Providers of consumer loans may require that consumers make a down payment 10 percent of the price of the purchased item.
hire purchase scheme drives a retailer’s interest margin too low, it will choose not to participate. We believe that a three percent interest margin (the Smart Fund charging a retailer five percent, the retailer charging consumers eight percent), combined with the anticipated increase in sales due to the low interest rates, will ensure retailer interest in the scheme.

Under a potential replication of the scheme, a retailer who wishes to participate in the subsidized hire purchase program should be given the opportunity to apply to become prequalified. A prequalified retailer would have the right to draw loans from the Smart Fund as it approves subsidized hire purchase plans without waiting for approval (up to a monthly cap). Prequalifying participating retailers will increase a retailer’s willingness to work with the Smart Fund, and reduce administrative burden for the Smart Fund’s administrator.

We expect that major retailers such as Courts, Dacosta Mannings, and Standard Distributors will want to take advantage of the subsidized hire purchase scheme and will apply for being the participating retailer in the pilot phase—the selected retailer will be interested in making the scheme work well, with a view to replicating the scheme on a larger scale. Subsequently under a possible replication, all retailers that wish to participate would be eligible to apply and become prequalified for loans subject to demonstrating financial solvency and sound screening systems for hire purchase eligibility.

Table L-1 illustrates how the Smart Fund would decrease the cost of hire purchase for consumers and decrease the cost of capital for retailers.

Table L-1: Demonstrating the Effect of the Smart Fund upon Hire Purchase

<table>
<thead>
<tr>
<th>Item</th>
<th>Rate (effective annual rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Retailers</strong></td>
<td></td>
</tr>
<tr>
<td>Retailers’ typical borrowing cost</td>
<td>12 percent</td>
</tr>
<tr>
<td>Retailers’ cost of borrowing from the Smart Fund</td>
<td>5 percent</td>
</tr>
<tr>
<td>Reduction in retailers’ cost of capital due to using the Smart Fund</td>
<td>7 percent</td>
</tr>
<tr>
<td><strong>Consumers</strong></td>
<td></td>
</tr>
<tr>
<td>Consumers’ typical interest rate in hire purchase schemes</td>
<td>23 percent</td>
</tr>
<tr>
<td>Hire purchase rate offered to consumers for EE/RE items by retailers that borrow from the Smart Fund</td>
<td>8 percent</td>
</tr>
<tr>
<td>Reduction in consumers’ interest rates provided by the Smart Fund</td>
<td>15 percent</td>
</tr>
</tbody>
</table>

**Recommending terms for loans to support subsidized hire-purchase**

We recommend that the Smart Fund’s subsidized hire purchase pilot scheme should offer below-market loans to retailers on the terms described below in Table L-2. Each of these terms is explained in greater detail later in this section.

Table L-2: Recommended Terms for Loans for Hire Purchase

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preauthorized loans</td>
<td>Participating retailers should be pre-authorized to immediately draw loans up to a monthly cap (to be determined separately for the pilot, and the potential replication)</td>
</tr>
</tbody>
</table>
### Principal

The principal amount of each loan should be equal to the purchase price of the EE (or) RE items that are being sold using hire-purchase.

### Interest

The Smart Fund must charge an interest rate that is low enough to entice retailers to participate in the subsidized hire-purchase scheme. We recommend setting a preliminary annual interest rate of five percent, with a negotiated maximum annual interest rate for consumers of eight percent. If after the first two years of the Smart Fund’s operations, these below-market rates are not low enough to adequately increase demand by retailers and consumers, Smart Fund manager should consider reducing the rates.

### Tenor

The tenor for the Smart Fund’s loans should be set at four years. This longer tenor should lead to greater demand for loans from the Smart Fund.

### Payment period

The Smart Fund’s loans should be repaid with interest in monthly payments.

### Allocating default risk

The retailers should bear the risk of consumer default. The Smart Fund should only bear the risk of retailer default.

### Security over loans

The Smart Fund should hold security over the hire-purchase payment plans that a retailer offers to consumers (ownership of the retailers’ hire-purchase schemes for EE and RE would pass to the Smart Fund if the retailers became insolvent).

### Pre-authorized loans

Retailers who choose to participate in the Smart Fund’s subsidized hire purchase scheme should be preauthorized to immediately draw loans up to a monthly cap. For the pilot phase, the cap could be about US$10,000, but this maximum amount could be set at US$100,000 if the program were replicated.

Retailers have expressed concern that a government-operated Smart Fund would not be as easy to work with as their typical private sector lenders. Preauthorizing retailers would eliminate this concern, making the Smart Fund simple for retailers to access. It would also ease the oversight burden for the Smart Fund administrator. In this way, the Smart Fund’s administrator will only need to verify after-the-fact that a drawdown has been tied to a legitimate transaction.

### Principal

The amount of principal for each loan should be equal to the purchase price of the EE or RE equipment that is being sold using hire-purchase. This parallel loan size will allow for simple oversight.

### Interest

The Smart Fund must set interest rates with a primary focus on ensuring that the subsidized hire-purchase scheme successfully increases demand—that retailers use its loans and consumers use the subsidized hire-purchase schemes offered by the retailers. Interest rates for the Smart Fund’s loans must be low enough to ensure adequate demand from both retailers and consumers. Secondary to this, the Smart Fund should try to charge an interest rate that is high enough to make this component of the Fund self-sustaining. These parameters lead to two questions:

- How low does the interest rate need to be to change consumer demand?
How high does the interest rate need to be to make the subsidized hire-purchase scheme self-sustaining?

*How low does the interest rate need to be to change consumer demand?*

The interest rate will only be low enough to increase demand if it significantly reduces the cost of borrowing through hire purchase schemes for consumers. We recommend capping at eight percent the effective annual interest rate that a participating retailer may charge consumers. Eight percent effective annual interest would be a 63 percent decrease below typical rates charged in hire-purchase schemes. A decrease of this magnitude should significantly increase demand.

The Smart Fund should charge a retailer an interest rate that allows it a reasonable spread between the rates at which it borrows from the Fund and the rates at which it provides credit to consumers through the hire purchase scheme. If this spread is too small, a retailer will likely choose not to participate in the subsidized hire purchase scheme. We believe that a three percent spread is large enough to generate retailer demand. For this reason, we recommend the Smart fund charge an effective annual interest rate to retailers of five percent.

The Smart Fund should be designed flexibly to take advantage of changes in interest appetite. If prevailing consumer and retail lending conditions in Barbados change, the interest rates charged by the Smart Fund may become too high or too low.

*How high does the interest rate need to be to make the subsidized hire-purchase scheme self-sustaining?*

To determine the interest rate that would need to be charged in order to make the subsidized hire purchase scheme self-sustaining, we test the scheme’s performance under reasonable scenarios for default. We developed a financial model for testing this issue. We define the subsidized hire purchase scheme as self-sustaining so long as the scheme’s principal is preserved (that is, if the amount of interest earned and principal repaid less defaults, operating expenses and principal disbursements is greater than zero).

Below, Table L-3 shows the results of our simulations. Assuming four-year tenors for the Fund’s loans, the Table shows the interest rate that the subsidized hire purchase scheme would need to charge in order to be considered self-sustaining at various levels of default.

**Table L-3: Interest Rates for the Hire Purchase Scheme to be Self-Sustaining**

<table>
<thead>
<tr>
<th>Annual Rate of Default</th>
<th>Annual Interest Rate to Be Self-Sustaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>1.9%</td>
</tr>
<tr>
<td>1%</td>
<td>2.4%</td>
</tr>
<tr>
<td>2%</td>
<td>2.9%</td>
</tr>
<tr>
<td>3%</td>
<td>3.5%</td>
</tr>
<tr>
<td>4%</td>
<td>4.0%</td>
</tr>
<tr>
<td>5%</td>
<td>4.5%</td>
</tr>
<tr>
<td>6%</td>
<td>5.1%</td>
</tr>
</tbody>
</table>
This table implies that our recommended initial effective annual interest rate, five percent, should be self-sustaining as long as participating retailers default on fewer than 6 percent of loans per year. Considering that retailers are well established businesses, and that the Fund will have security over the underlying loans, this assumption is probably tenable. However, Government should be aware that it may err on the optimistic side, meaning that government may not be fully compensated for bearing retailer default risk with an interest rate of 5 percent. If it proves possible after the Fund is established to slightly increase its interest rates without decreasing demand for its funds, this would be worth considering in order to more fully compensate for the default risk. This matter will benefit from the facility being initially launched as a pilot initiative—useful lessons learned are likely to arise for a potential replication of the initiative on a larger scale.

**Tenor**

We recommend setting the tenor for the Smart Fund’s loans at four years. This is longer than the typical tenor for a hire purchase scheme (about three years). The longer tenor should increase the attractiveness of the loans offered by the Smart Fund by increasing their net present value. When the interest rate that the Smart Fund charges is below a retailer's weighted average cost of capital, as the recommended five percent annual rate surely is, a longer tenor increases the net present value of the loans.

**Payment period**

Principal should be repaid with interest in monthly installments. This mimics the payment period of a retailer’s hire purchase scheme.

**Allocating default risk**

A retailer is best positioned to bear the risk of consumer default on hire purchase payments. A retailer’s hire purchase scheme is already designed to account for this default risk, and it has systems in place to effectively mitigate much of it. The Smart Fund will bear the risk of retailer default on loan repayments, and should mitigate this risk by holding security over the targeted hire-purchase arrangements.

**Security over loans**

The Smart Fund should mitigate its risk of retailer default by holding security over the hire-purchase plans against which the loans have been taken. In this way, if a retailer defaults on loan repayments, the ownership of the flow of funds from the retailer’s hire purchase plan will pass to the Smart Fund.

**L.2.2 Compact Fluorescent Lamps Promotion, US$0.5 million**

We recommend putting in place a US$0.5 million grant program to distribute free CFLs. This program would reimburse retailers who give away CFLs to consumers.

CFLs are already economically efficient—they are cheaper over their lifetime than incandescent bulbs—but the market for CFLs in Barbados does not yet function properly. CFLs are not readily available for purchase at retailers and consumer demand for CFLs is low.

Paying retailers to give away US$0.5 million of CFLs should jumpstart this market, increasing availability, allowing retailers to achieve some economies of scale in their procurement processes, and increasing demand amongst consumers who have not yet tried using CFLs. Below, we illustrate how the grant facility for CFLs should work.
Designing a grant facility for CFLs

A grant facility for CFLs must not only cover the cost to retailers of purchasing the CFLs, but also give the retailers proper incentives to participate in the scheme. We recommend that, in addition to subsidizing 100 percent of the wholesale cost of CFLs, the CFL giveaway scheme should allow retailers to stipulate that they will only give away CFLs in conjunction with purchase of other items that meet an agreed minimum purchase price (for example, BB$10). Also, a maximum number of CFLs given away should be set (for example, five bulbs per customer per day) to prevent customers from gaming the giveaway scheme.

The cash flows of the proposed CFL program would look like this:

- The Smart Fund provides funds to each retailer equal to 100 percent of the purchase price of all CFLs that that retailer agrees to give away (the aggregate amount of funds provided to all retailers would be no more than US$0.5 million)
- The retailers use those funds to purchase CFLs
- Each retailer gives away CFLs to customers who make a qualifying minimum purchase from that retailer.

We expect that all CFLs could be given away during the first year of the Fund—this would correspond to 100,000 CFLs assuming a unit cost of US$5, as summarized in Table L-4. Management fees would be 1 percent on grant funds disbursed.

Table L-4: CFL Promotion

<table>
<thead>
<tr>
<th></th>
<th>Y1</th>
<th>Y2</th>
<th>Y3</th>
<th>Y4</th>
<th>Y5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total available BoY Units</td>
<td>US$ 1,000s</td>
<td>500</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Grants used</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount per grant</td>
<td>Grants 100,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amount used for the year</td>
<td>US$ 1,000s</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td>Total available EoY Units</td>
<td>US$ 1,000s</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cumulative CFLs Sponsored</td>
<td>CFLs 100,000</td>
<td>100,000</td>
<td>100,000</td>
<td>100,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Total reduction in electricity use kwh/year</td>
<td>8,210,000</td>
<td>8,210,000</td>
<td>8,210,000</td>
<td>8,210,000</td>
<td>8,210,000</td>
</tr>
<tr>
<td>Total annual reduction tonnes of CO2</td>
<td>7.221</td>
<td>7.221</td>
<td>7.221</td>
<td>7.221</td>
<td>7.221</td>
</tr>
<tr>
<td>Cumulative reduction tonnes of CO2</td>
<td>7.221</td>
<td>14,442</td>
<td>21,663</td>
<td>28,884</td>
<td>36,105</td>
</tr>
<tr>
<td>Management fees - percentage of funds disbursed percent</td>
<td>1.0%</td>
<td>1.0%</td>
<td>1.0%</td>
<td>1.0%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Management fees US$ 1,000s</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

L.2.3 Air Conditioner (A/C) Rebate Trade-In Program, US$1.5 million

We recommend putting in place a US$1.5 million grant program to replace inefficient air conditioning units with new energy efficient air conditioners. This program would provide subsidies for increasing the demand and supply of energy efficient air conditioners. This would jumpstart the market for these appliances. The subsidy would be limited to those who exchange old air conditioners for efficient ones, therefore reducing the risk that the subsidy would inadvertently increase total air-conditioning load by subsidizing people to buy air-conditioners when they would otherwise choose to do without.

31 The Smart Fund should work with retailers and wholesalers to set a standard rate it will pay per CFL—we assumed US$5.
We recommend that the grant program subsidize 50 percent of the retail cost of air-conditioners for small and medium industrial and commercial businesses. Split A/C systems (the most common for businesses) cost about US$2,000—about 40 percent to 60 percent more than an equivalent one with conventional efficiency. A 50 percent subsidy is a judgment to balance incentives to participate (which point toward a larger subsidy percentage) and the number of units that can be subsidized (which points toward a lower subsidy level per unit). Assuming that an efficient unit costs 60 percent more than a conventional unit, this would mean that the non-subsidized costs would be US$2,000 and US$1,250, respectively. A 50 percent rebate would make enough of a difference to provide an incentive for participating (the effective cost to the beneficiary would be US$1,000, or US$250 less than a conventional one). A lower rebate might risk preventing the program from functioning.

**Designing a rebate trade-in program for energy efficient air conditioners**

We recommend that the grant facility for energy efficient air conditioners operate through discount certificates issued by the Smart Fund. There could be two types of certificates, one for US$250 for energy efficient window-mounted A/C units (estimated to cost about US$500) and the other for US$1000 for energy efficient split units (estimated to cost US$2000). If desired, there could also be just one type of certificate for split systems—this would mean targeting the facility on businesses, which represent the customers using this technology.

Table L-5 below summarizes what the Program could look like if only split systems for businesses were supported—funds would be disbursed in the first two years of the Smart Fund’s activity. As for CFLs, there would be a 1 percent management fee on funds disbursed.

**Table L-5: A/C Rebate Trade-In Program**

<table>
<thead>
<tr>
<th>Units</th>
<th>Y1</th>
<th>Y2</th>
<th>Y3</th>
<th>Y4</th>
<th>Y5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total available BoY</td>
<td>US$ 1,000s</td>
<td>1,500</td>
<td>500</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Grants used</td>
<td>Grants</td>
<td>1,000</td>
<td>500</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amount per grant</td>
<td>US$ 1,000s</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Amount used for the year</td>
<td>US$ 1,000s</td>
<td>1,000</td>
<td>500</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total available EoY</td>
<td>US$ 1,000s</td>
<td>500</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total ACs Sponsored</td>
<td>Acs</td>
<td>1,000</td>
<td>1,500</td>
<td>1,500</td>
<td>1,500</td>
</tr>
<tr>
<td>Total reduction in electricity use</td>
<td>kWh</td>
<td>2,308,000</td>
<td>3,462,000</td>
<td>3,462,000</td>
<td>3,462,000</td>
</tr>
<tr>
<td>Total annual reduction</td>
<td>tonnes of CO2</td>
<td>2,030</td>
<td>3,045</td>
<td>3,045</td>
<td>3,045</td>
</tr>
<tr>
<td>Cumulative reduction</td>
<td>tonnes of CO2</td>
<td>2,030</td>
<td>5,075</td>
<td>8,120</td>
<td>11,165</td>
</tr>
<tr>
<td>Management fees - percentage of funds disbursed</td>
<td>percent</td>
<td>1.0%</td>
<td>1.0%</td>
<td>1.0%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Management fees</td>
<td>US$ 1,000s</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Certificates would drive the cash flows of the grant program like this:

- The Smart Fund provides discount certificates to all retailers that choose to participate in the energy efficient air conditioner grant program. The aggregate value of these certificates should be no more than US$1.5 million.
- Participating retailers issue discount certificates to customers in exchange for old air conditioning units, then destroy and safely dispose of the exchanged units in accordance with Barbados law.

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32 Stantec estimate based on North American market experience.
Customers who receive discount certificates apply them toward the price of an approved energy efficient unit. These customers must purchase A/C units from the same store where they exchange their old units.

The retailers then cash in used certificates with the Smart Fund.

The Smart Fund audits participating retailers to check that they are following the rules of the exchange program.

L.2.4 Energy Efficiency Retrofit and Renewable Energy Finance Facility, US$6.5 million

Based on Government preferences, a US$6.5 million facility will be put in place to provide below-market loans and contingent subsidies to reduce the cost of EE retrofits and deployment of small RE systems to businesses. ESCOs could be procured to finance capital works for retrofits. ESCO would receive their returns through a share of the savings achieved. ESCO contracts provide for use of a wide variety of efficient technologies. A typical retrofit might introduce roof straps, window shutters, improved insulation, efficient appliances (air conditioners, refrigeration, motors), and efficient lighting. For small RE systems, we recommend limiting eligibility to economically viable solar technologies—selected solar PV systems, hybrid solar PV/thermal systems, and solar water heaters. Small wind systems should not be supported, as they would increase the cost of energy for Barbados.

Providing concessional loans and contingent subsidies should spur supply and demand for retrofits and small RE systems. These types of financial instruments should spur demand by reducing upfront costs and increasing the net present value of retrofit investments. Additionally, the size of the program should encourage suppliers to meet anticipated demand—driving ESCOs and energy efficiency auditors to improve the scale and availability of their businesses within Barbados.

Designing the EE Retrofit and RE Finance Facility

The Fund manager will use this facility to provide loans directly to businesses at 5 percent, and charge a 1.5% management fee as a margin on interest. It is difficult to predict the actual loans that would be given out—these could be either for a RE system, or for an EE retrofit, or for both interventions packaged together. Loan sizes should be limited to a cap—we suggest US$25,000 for either a RE system or a EE retrofit. This would ensure that the beneficiaries of the facility are small and medium businesses.

The Government is funding an initial set of energy efficiency audits for 25 households and 8 businesses. Depending upon loan approvals, these households and businesses should be the initial 33 recipients of concessional loans. Further recipients may become eligible for financing if they complete an energy efficiency audit (carried out by a certified auditor). The Smart Fund will provide conditional subsidies to cover the full cost of these audits, with consumers receiving subsidies if they undertake audits and subsequently undergo retrofits.

Table L-6 shows the balance sheet of the facility under one possible scenario—RE loans of about US$23,800 (corresponding to a 5kW LCPV single axis tracking system), EE loans of US$10,000 (including a package of 10 T8 lighting fixtures with occupancy sensors, 10 CFLs, a split A/C system, an efficient motor, a power monitor, and an audit), and a maximum of US$1.5 million disbursed in soft loans each year (this would imply about 32 RE loans, and 74 EE loans). The audit for a retrofit could be considered as an item of the EE loan itself—it
would also be possible to limit the share of audit cost the Fund covers to 50 percent, for providing some upfront cost sharing by the beneficiary.

**Table L-6: EE Retrofit and RE Finance Facility**

<table>
<thead>
<tr>
<th>Units</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Year 6</th>
<th>Year 7</th>
<th>Year 8</th>
<th>Year 9</th>
<th>Year 10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current Assets</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash US$ 1,000s</td>
<td>6,125</td>
<td>5,468</td>
<td>4,622</td>
<td>3,683</td>
<td>3,123</td>
<td>2,848</td>
<td>2,766</td>
<td>2,780</td>
<td>2,794</td>
<td>2,808</td>
</tr>
<tr>
<td><strong>Total Current Assets</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fixed Assets</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loans US$ 1,000s</td>
<td>375</td>
<td>1,038</td>
<td>1,898</td>
<td>2,859</td>
<td>3,445</td>
<td>3,743</td>
<td>3,843</td>
<td>3,843</td>
<td>3,843</td>
<td>3,843</td>
</tr>
<tr>
<td><strong>Total Fixed Assets</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Assets</strong></td>
<td>US$ 1,000s</td>
<td>6,500</td>
<td>6,506</td>
<td>6,520</td>
<td>6,542</td>
<td>6,568</td>
<td>6,591</td>
<td>6,609</td>
<td>6,623</td>
<td>6,637</td>
</tr>
<tr>
<td><strong>Liabilities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Liabilities</strong></td>
<td>US$ 1,000s</td>
<td>6,500</td>
<td>6,500</td>
<td>6,500</td>
<td>6,500</td>
<td>6,500</td>
<td>6,500</td>
<td>6,500</td>
<td>6,500</td>
<td>6,500</td>
</tr>
<tr>
<td><strong>Equity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paid-in Capital US$ 1,000s</td>
<td>6,500</td>
<td>6,500</td>
<td>6,500</td>
<td>6,500</td>
<td>6,500</td>
<td>6,500</td>
<td>6,500</td>
<td>6,500</td>
<td>6,500</td>
<td>6,500</td>
</tr>
<tr>
<td>Retained Earnings US$ 1,000s</td>
<td>0</td>
<td>6</td>
<td>20</td>
<td>42</td>
<td>68</td>
<td>91</td>
<td>109</td>
<td>123</td>
<td>137</td>
<td>151</td>
</tr>
<tr>
<td><strong>Total Equity</strong></td>
<td>US$ 1,000s</td>
<td>6,500</td>
<td>6,506</td>
<td>6,520</td>
<td>6,542</td>
<td>6,568</td>
<td>6,591</td>
<td>6,609</td>
<td>6,623</td>
<td>6,637</td>
</tr>
<tr>
<td><strong>Total Equity &amp; Liabilities</strong></td>
<td>US$ 1,000s</td>
<td>6,500</td>
<td>6,506</td>
<td>6,520</td>
<td>6,542</td>
<td>6,568</td>
<td>6,591</td>
<td>6,609</td>
<td>6,623</td>
<td>6,637</td>
</tr>
</tbody>
</table>

**L.2.5 Discretionary Facility, US$1.0 million**

Simple, discretionary subsidies can achieve quick results (even on a one-time or temporary basis), especially as a means of lowering project preparation costs. Discretionary subsidies also give the Government flexibility to allocate funds based upon lessons learned from the SEF Pilot Program. For instance, funds from the discretionary facility might be used to replicate or extend CFL distribution, financing of small PV systems, or awareness initiatives (supported by distribution of further power monitors).

The Discretionary Facility would also provide funds for paying the administrative cost of the Fund’s two grant facilities (CFL Promotion, and A/C Rebate Trade-In) through a 1 percent management fee on amounts disbursed. It is important to note that, on the other hand, the Fund’s two loan facilities (Hire Purchase, and EE Retrofit and RE Finance) would provide for the management fee of 1.5 percent as a margin on interest charged to final customers.

Table L-7 shows one possible scenario of the Discretionary Facility, under which the Government would

- Pay a 1 percent management fee to the Fund Manager for the Fund’s two grant facilities (CFLs and A/Cs)
- Provide further grants for free CFLs (15W)
- Provide further grants for buying small PV systems (2kW thin-film systems with fixed mounting)
- Spend remaining resources for awareness campaigns.

This facility would of course generate no revenue for the Smart Fund.
Table L-7: Discretionary Facility

<table>
<thead>
<tr>
<th>Units</th>
<th>Y1</th>
<th>Y2</th>
<th>Y3</th>
<th>Y4</th>
<th>Y5</th>
<th>Y6</th>
<th>Y7</th>
<th>Y8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total available BoY</td>
<td>US$ 1,000s</td>
<td>1,000</td>
<td>250</td>
<td>184</td>
<td>123</td>
<td>61</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Funds used to pay management fees for other grants</td>
<td>US$ 1,000s</td>
<td>15</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Awareness programs</td>
<td>US$ 1,000s</td>
<td>245</td>
<td>61</td>
<td>61</td>
<td>61</td>
<td>61</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>PVs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Funds available - BoY</td>
<td>US$ 1,000s</td>
<td>245</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Grants used</td>
<td></td>
<td>Grants</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amount per grant</td>
<td>US$ 1,000s</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>total for year</td>
<td>US$ 1,000s</td>
<td>245</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Funds available - EoY</td>
<td>US$ 1,000s</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>CFLs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Funds available - BoY</td>
<td>US$ 1,000s</td>
<td>245</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Grants used</td>
<td></td>
<td>Grants</td>
<td>49,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Amount per grant</td>
<td>US$ 1,000s</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
</tr>
<tr>
<td>total for year</td>
<td>US$ 1,000s</td>
<td>245</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Funds available - EoY</td>
<td>US$ 1,000s</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Total available EoY | US$ 1,000s | 250 | 184 | 123 | 61 | 0 | 0 | 0 |

Cumulative CFLs Sponsored | CFLs | 49,000 | 49,000 | 49,000 | 49,000 | 49,000 | 49,000 | 49,000 |
Total reduction in electricity use | kwh/year | 4,022,900 | 4,022,900 | 4,022,900 | 4,022,900 | 4,022,900 | 4,022,900 | 4,022,900 |
Total annual reduction | tonnes of CO2 | 3,538 | 3,538 | 3,538 | 3,538 | 3,538 | 3,538 | 3,538 |
Cumulative reduction | tonnes of CO2 | 3,538 | 7,077 | 10,615 | 14,153 | 17,691 | 21,230 | 24,768 | 28,308 |
Cumulative PVs Sponsored | CFLs | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
Total reduction in electricity use | kwh/year | 87,514 | 87,514 | 87,514 | 87,514 | 87,514 | 87,514 | 87,514 |
Total annual reduction | tonnes of CO2 | 77 | 77 | 77 | 77 | 77 | 77 | 77 |
Cumulative reduction | tonnes of CO2 | 77 | 154 | 231 | 308 | 385 | 462 | 539 | 616 |

L.3 Eligibility for Receiving Support from the Fund

We recommend that all households (regardless of income levels) and all businesses (except for hotels) be eligible for receiving support from the Fund—although different components could target different customer types. This recommendation links with the Government’s high-level objectives of reducing energy costs, improving energy security, and enhancing environmental sustainability. High-income households and large businesses can contribute to these objectives just as well as low and middle-income households and small and medium-sized businesses.

The Fund’s different facilities could have different eligibility criteria:

- The grant facilities (A/C and CFLs) and the Hire Purchase facility would ultimately benefit households, although they would work through retailers
- The EE Retrofit and RE Finance facility could be targeted to businesses only.

Government entities should not be eligible for receiving any support from the Fund. Government is already providing separate budget allocations for investments by government entities in EE and RE investments under the Public Sector Energy Conservation Program.

The Government has indicated that hotels should be eligible for the EE Retrofit and RE Finance facility, in spite of the fact that specific financial instruments to promote EE and RE investments in hotels will be provided by a separate Fund that is being developed under the Caribbean Hotel Energy Efficiency Action Program (CHENACT).

Government representatives also indicated during the Presentation on 1 December 2009 that state-owned enterprises should not be eligible for receiving support from the Fund. Table L-8 below summarizes customer eligibility for Fund support.
Table L-8: Eligible Customers for Smart Fund Support

<table>
<thead>
<tr>
<th>Type of customer</th>
<th>Recommended eligibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low/middle-income households</td>
<td>✓</td>
</tr>
<tr>
<td>High-income households</td>
<td>✓</td>
</tr>
<tr>
<td>Small/medium businesses</td>
<td>✓</td>
</tr>
<tr>
<td>Large businesses</td>
<td>✓</td>
</tr>
<tr>
<td>Hotels (for the EE Retrofit and RE Finance Facility only)</td>
<td>✓</td>
</tr>
<tr>
<td>Government entities</td>
<td></td>
</tr>
<tr>
<td>State-owned enterprises</td>
<td></td>
</tr>
</tbody>
</table>

L.4 Arrangements for Administering the Smart Fund

We have four main recommendations for administering the Smart Fund:

- A unit within the Ministry of Finance, Investment, Telecommunications, and Energy (MFIE) should supervise the Fund’s management, but management itself can be outsourced to the Enterprise Growth Fund Limited (EGFL)
- The Fund should support EE and RE through the same entity
- Budgeting guidelines should be set for the first two years of operation, with adjustment of the indicative budgets based on market feedback thereafter
- The Government should consider other potential sources of funding to further capitalize the Fund in future.

L.4.1 Fund management by the Enterprise Growth Fund Limited (EGFL) under MFIE supervision

The Smart Fund should be supervised within the Ministry of Finance, Investment and Energy, but—as suggested by the Government—the actual management of the Funds can be outsourced to the Enterprise Growth Fund Limited (EGFL) against payment of a spread for the loan components (EE Retrofit and RE Finance Facility, and Pilot Consumer Finance Facility), and of a disbursement fee for grant components (Air conditioner rebate trade-in program, and CFL promotion).

Outsourcing its management to the Enterprise Growth Fund Limited (EGFL) seems a reasonable option based on our conversations with them and our analysis of their experience and skills:

- The EGFL has significant experience in providing credit to small and medium enterprises in Barbados—this is consistent with the Smart Fund’s main focus on SMEs—and in channeling Government funds

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33 Conversations with the EGFL, 17 September 2009, and 3 June 2010. [www.egfl.bb](http://www.egfl.bb)
The EGFL is open to different arrangements regarding the spread it would apply on Government funds for its clients—this could be a fixed spread negotiated with Government, as well as a flexible spread within an agreed range (1-2 percent, according to the EGFL’s experience).

The EGFL has solid and established contacts with private companies through Barbados’ key SME associations—in particular the Barbados Manufacturers’ Association, the Small Business Association of Barbados—and has used such associations for effectively marketing its credit products with companies.

The EGFL can also administer grants from the Government, with payment of a disbursement fee (up to 1 percent on funds disbursed).

### L.4.2 One entity for EE and RE

We recommend that there be only one Fund providing financial support for both EE and RE investments, for the following three reasons:

- The instruments we recommend can be applied to investments in EE and RE projects
- EE and RE address two sides of the same topic—sustainable energy—on the demand side and the supply side, respectively
- The Fund’s budget should be sufficiently flexible to react to market feedback—as we explain in our following recommendation—and support the most viable investment opportunities, be they EE or for RE.

### L.4.3 Budgeting: guidelines and flexibility

We recommend setting some initial budgeting guidelines for the Fund’s first two years of operation. After two years of operation—earlier, if necessary—the managers of the Fund should be able to adjust the budgeting guidelines in response to market feedback. The feedback will come from the performance of the Fund’s activities, customers’ responses to services offered, and the outcome of the SEF Pilot Program (which will be launched in 2010, and includes support to both EE and RE investments).

### L.4.4 Consider other sources of funding

The US$10 million investment loan from the IDB could be complemented by other sources of funding. Additional funding would allow the Fund to support more EE and RE investments over a longer timeframe. The Government should consider additional annual budgetary allocations for capitalizing the Fund.

Finally, the Government should explore the potential to obtain funding from international organizations other than the IDB—for example, the Caribbean Development Bank is considering an intervention in sustainable energy. During the meetings we held with the Government and the IDB in November 2009, the IDB also indicated the possibility that the US$10 million Investment Loan could be the first installment of a credit line under which the Government could request subsequent installments that would be approved in an expedited process. The Government has indicated that it could consider a second phase of the Investment Loan.

Figure L-1 shows the Fund’s proposed structure under the arrangements we describe in this Appendix.
Figure L-1: Proposed Smart Fund Structure

- IDB Government
  - Investment Loan (US$10M)
  - Repayment of principal and interest

- Fund Manager (EGFL)
- Oversight (MFIE)

- Smart Fund
  - Fund capitalization
  - Other sources of funding
  - Financing
    - Financial returns
    - Economic returns

- Pilot Hire Purchase
- CFL Promotion
- A/C Rebate Trade-In
- EE Retrofit & RE Finance
- Discretionary Facility

- Retailer(s)
- Customers
  - EE/RE investment

- Retailers
  - Customers
  - EE/RE investment

- Customers
  - EE/RE investment

- Non-revenue activities
  - Consumers or Suppliers
    - EE/RE investment

- Consumers or Suppliers

- Barbadian society and economy
Appendix M: Assumptions and Results for Projected Benefits of the SEF

In this Appendix, we discuss the assumptions and the results from each of the four scenarios.

- In Section M.1, we explain the methodology we used and the general assumptions we made for forecasting electricity supply and demand over the next 20 years in Barbados
- In Section M.2 to Section M.5, we explain the specific assumptions we made for the each of the four scenarios and the results of our modeling

M.1 Modeling Approach and Assumptions

In this section, we describe the four scenarios used to project future electricity supply and demand in Barbados in more detail. We also list the general assumptions that are made across all four scenarios.

Description of scenarios

We have created a model of the electricity sector in Barbados for projecting demand and supply over the next 20 years. In the model we have specified the following four scenarios to analyze different investment patterns and inform policy-making decisions:

- **Business as usual scenario**—BL&P invests in new thermal generation capacity to replace decommissioned plants and meet peak and annual demand growth. The only investment in renewable energy is the planned Lamberts wind farm, and no investment occurs in energy efficiency. This scenario is based on BL&P’s capital expansion plan. The only difference is that we moved medium speed diesel D17 forward from 2013 to 2012 to keep the reserve capacity margin above 20 percent for 2012

- **High RE scenario**—New generation investment focuses on renewable energy resources identified in the sustainable energy matrix—up to a capacity of 40MW of wind energy, 13.5MW of solid waste, and 20MW of cogeneration. New thermal capacity is commissioned to ensure the reserve capacity margin calculated based on firm capacity is above 20 percent and to meet annual demand growth. No investment for energy efficiency is made

- **High EE scenario**—In this scenario, residential, commercial, and industrial consumers invest in the economically-feasible energy efficiency appliances and equipment identified in the sustainable energy matrix. The overall growth in energy consumption reduces from 2.14 percent per year to 0.97 percent, and growth in peak demand falls 2.18 percent per year to 1.04 percent

- **Sustainable Energy scenario**—BL&P invests in all the renewable energy projects identified in the sustainable energy matrix and customers invest in all economically-feasible energy efficiency appliances and equipment identified in the sustainable energy matrix.
We use these scenarios to illustrate how the demand and supply of electricity in Barbados could change over the next 20 years, and assess sector outcomes against government objectives.

**General assumptions applied in all scenarios**

In addition to specific assumptions on investments in energy efficiency and renewable energy, we have made a number of general assumptions in our sector model that apply across all scenarios.

**Customer growth**

In section 2.2, we analyzed the rate of customer number growth across different customer classes over the past ten years. Based on these recent trends and our expectations around future customer numbers we have assumed the following growth in customer numbers:

- **Residential customers**—Growth rate of 1.4 percent based on the historical trend
- **Commercial customers**—Growth rate of 5 percent over the next five years, falling to 3 percent the following five years (2014-2019) and 2 percent thereafter. In the past ten years commercial customer numbers have grown by 7 percent annually, although we expect this growth rate to fall as the number of companies operating in certain sectors (such as tourism) stabilizes
- **Industrial customers**—Growth rate of 1.5 percent based on the historical trend.

**Average consumption per customer**

Together with customer numbers, average consumption per customer makes up the demand forecast for each customer class. Average consumption per customer is projected based on the historical trend. Under the high energy efficiency scenario, growth in average consumption per customer is calculated by subtracting the improvement in energy efficiency from the historical growth rate. The reduction achieved by energy efficiency is calculated in the sustainable energy matrix.

**Peak Demand**

Peak demand is projected based on historical correlation between peak demand and residential consumption, commercial consumption, and industrial consumption. Under the high energy efficiency and sustainable energy scenarios, peak demand is lower as a result of lower consumption by all three customer categories.

**Capacity reserve margin**

Over the past ten years (from 2000 to 2009), the reserve capacity margin has varied between 6 to 54 percent, and currently stands at around 43 percent. As discussed in Section 2.5, most electricity systems target reserve capacity margins of at least 15 percent using a planning standard that allows back-up of the largest single unit to ensure that the system can withstand unplanned outages. We assume that to maintain reliable supply, the reserve capacity margin calculated based on firm capacity is maintained above 20 percent. Firm capacity is the capacity that an electricity system can depend on during peak hours. Wind and solar generation is normally not considered as firm capacity.
**Discount Rate**

We used a real discount rate of 6 percent based on the average historical returns to BL&P.

**Losses**

Transmission and distribution losses are assumed to remain at current levels of 6.3 percent and energy for BL&P’s own use is similarly assumed to remain at 4.1 percent. This is a relatively low level of losses, and we consider that higher efficiency gains are unlikely without significant investment.

**Plant operation and dispatch**

BL&P will continue to operate and dispatch generation plants based on short run operating costs, with lower cost plants dispatched first to meet demand. In practice, this means that BL&P will operate renewable plants first (depending on availability), followed by low and medium speed diesel plants, and only operate gas turbines when required.

**Renewable generation investment**

Table M-1 lists the investments in new renewable generation that are included in the model. These assumptions are generated based on our understanding of limitations on the availability of renewable resources in Barbados detailed Section 4.2.

**Table M-1: Assumptions on Renewable Generation Investment**

<table>
<thead>
<tr>
<th>Generating Unit (Location)</th>
<th>Maximum Continuous Rating (MW)</th>
<th>Capital Costs (US$/kW)</th>
<th>Fuel Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>From BL&amp;P Capital Expenditure Plan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamberts Wind Farm</td>
<td>10</td>
<td>1,860</td>
<td></td>
</tr>
<tr>
<td>subtotal</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Renewable Plants in the Model</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cogeneration</td>
<td>20</td>
<td>2,976</td>
<td>Sugar Cane</td>
</tr>
<tr>
<td>Solid Waste</td>
<td>13.5</td>
<td>11,111</td>
<td>Solid Waste</td>
</tr>
<tr>
<td>Wind 2</td>
<td>10</td>
<td>1,860</td>
<td></td>
</tr>
<tr>
<td>Wind 3</td>
<td>10</td>
<td>1,860</td>
<td></td>
</tr>
<tr>
<td>Wind 4</td>
<td>10</td>
<td>1,860</td>
<td></td>
</tr>
<tr>
<td>subtotal</td>
<td>63.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>73.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: BL&P Capital Expenditure Plan and Sustainable Energy Matrix

We have assumed that a total of 73.5MW of renewable capacity is technically viable based on technologies that are currently commercially viable or likely to become viable in the foreseeable future. Investing in all of this potential renewable capacity would result in 37
percent of energy being generated by renewable sources by 2026 in the sustainable energy scenario, which is almost twice the Government target. The timing of renewable energy investments is detailed in Section 4.2.

**Thermal generation investment**

Table M-2 lists the investments in new thermal generation included in the model. We have assumed that larger generation units will become viable in Barbados at some time in the future, which is reflected in future units having an installed capacity of 32MW rather than the current unit size of 16MW.

**Table M-2: Assumptions on Thermal Generation Investment**

<table>
<thead>
<tr>
<th>Generating Unit (Location)</th>
<th>Maximum Continuous Rating (MW)</th>
<th>CO(_2) Emissions Factor (tCO(_2)e/MWh)</th>
<th>Capital Costs (BB$/kW)</th>
<th>Fuel Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>From BL&amp;P Capital Expenditure Plan</td>
<td>Medium Speed Diesel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit D16</td>
<td>16</td>
<td>0.69</td>
<td>2,985</td>
<td>HFO</td>
</tr>
<tr>
<td>Unit D17</td>
<td>16</td>
<td>0.69</td>
<td>2,985</td>
<td>HFO</td>
</tr>
<tr>
<td>Unit D18</td>
<td>16</td>
<td>0.69</td>
<td>2,985</td>
<td>HFO</td>
</tr>
<tr>
<td>Subtotal</td>
<td>48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Thermal Plants in the Model</td>
<td>Medium Speed Diesel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D19</td>
<td>16</td>
<td>0.69</td>
<td>2,985</td>
<td>HFO</td>
</tr>
<tr>
<td>D20</td>
<td>32</td>
<td>0.69</td>
<td>2,985</td>
<td>HFO</td>
</tr>
<tr>
<td>D21</td>
<td>32</td>
<td>0.69</td>
<td>2,985</td>
<td>HFO</td>
</tr>
<tr>
<td>D22</td>
<td>32</td>
<td>0.69</td>
<td>2,985</td>
<td>HFO</td>
</tr>
<tr>
<td>Subtotal</td>
<td>112.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas Turbines</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GT07</td>
<td>32</td>
<td>0.95</td>
<td>1,750</td>
<td>Jet Fuel</td>
</tr>
<tr>
<td>GT08</td>
<td>32</td>
<td>0.95</td>
<td>1,750</td>
<td>Jet Fuel</td>
</tr>
<tr>
<td>Subtotal</td>
<td>64</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>224</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: BL&P
**Timing of new generation investments**

New thermal generation is assumed to be built as needed to meet demand—ensuring both that the reserve capacity margin calculated based on firm capacity does not fall below 20 percent and that the system is able to generate sufficient energy to meet annual demand.

**Fuel Prices**

Barbados mainly consumes three types of fuel: heavy oil fuel, jet fuel and diesel. Fuel prices are volatile and it is very difficult to predict what the price will be in the future. We have therefore forecast light sweet crude oil price for the next 20 years based on its forward contract prices from NYMEX. We then forecast the price of the three types of fuel based on the historical correlation between the fuel price and light sweet crude oil price. The results of our forecast are shown in Figure M-1.

**Figure M-1: Forecasted Fuel Prices**

![Fuel Price Outlook Graph](attachment://fuel_price_outlook.png)

*Source: NYMEX Light Sweet Crude Oil Future*

*Notes: We assumed the light sweet crude oil price will follow current forward contract prices, which are trading at US$ 80.73 per barrel for December 2010 delivery and US$ 95.75 per barrel for 2017 delivery. Light sweet crude oil price is assumed to reach US$ 100 per barrel by 2020 and then stays at US$ 100 per barrel until 2029. See [www.nymex.com](http://www.nymex.com).*

**CO₂ Emissions**

We calculated CO₂ emission based on carbon emission factor we have assumed for each plant and the amount of electricity dispatched by that plant based on our dispatch calculation.

**Distributed Generation**

In the high renewable energy and sustainable energy scenarios, we assume that households and businesses in Barbados will invest in small scale wind and solar in accordance with the capacity and timing in the sustainable energy matrix detailed in Section 4.2.
M.2 Business as Usual Scenario

The business as usual scenario is used for a comparison with the costs of renewable energy and energy efficiency calculated in the other three scenarios. We would expect these outcomes to result from there being insufficient incentives for energy efficiency or renewable energy investment.

In the reminder of this section, we present:

- Scenario-specific assumptions
- Projected demand
- Projected supply
- Sector outcomes for CO₂ emissions, fuel costs and capital expenditure, and the proportion of energy generated from renewable sources.

Scenario-specific assumptions

In addition to the general assumptions described in Section M.1, we have made the following specific assumptions in the business as usual scenario:

- **Demand:** With no incentives to invest in energy efficiency, average consumption per customer and peak demand will grow at historical levels. This implies that total energy consumption per customer will grow at the historical rate for all three categories of customers. The overall consumption will grow at around 2.55 percent per year.

- **Supply:** With no incentives to build additional renewable generation capacity, BL&P will build the thermal plants and Lamberts Wind Farm currently in its capital expenditure plan, followed by more thermal plants.

Projected Demand

The Figure below illustrates projected electricity demand in the business as usual scenario. Demand from commercial customers remains a relatively constant portion of total demand. Most of the growth in demand comes from residential customers. The share of electricity demand from residential customers is projected to grow from 32 percent to around 42 percent of total consumption. Peak demand is shown by the line in the Figure M-2 and reaches 259MW by 2029.
Projected Supply

Figure M-3 lists the new generation investment that will need to be made to meet forecast energy demand and maintain an adequate reserve capacity margin. The new plants commissioned in each year are listed at the top of each bar, and decommissioned plants are listed in parenthesis.
Figure M-3: Projected Generation Expansion Plan in Business as Usual Scenario

Figure M-4 shows the energy generated by plant type over the next 20 years in the business as usual scenario. Generation plants are operated on least-cost basis with renewable energy dispatched whenever available. Energy generated from medium speed diesels increases gradually as new plants are commissioned, replacing generation from low speed diesel. The steam plants will be phased out from the system in 2012 and generation from gas turbines remains relatively steady.

Figure M-4: Energy Generated by Plant Type in Business as Usual Scenario
**Relevant Results**

Our projections of demand and supply enable the following results to be calculated for the business as usual scenario:

- CO₂ emissions
- Fuel costs and capital expenditure
- Proportion of energy generated by renewable sources

**CO₂ emissions**

In 2009, BL&P produced 832,000 tons of carbon dioxide (tCO₂) from electricity generation. Under the business as usual scenario, the annual CO₂ emissions will decrease briefly between 2011 and 2013 to around 792,000 tCO₂, as relatively CO₂ intensive steam generating plants are decommissioned and the Lamberts wind farm is added to the system. CO₂ emissions will then increase as BL&P resumes building more thermal plants to meet growing demand. In 2029, we expect BL&P to produce more than 1.15 million tCO₂ under the business as usual scenario. Figure M-5 shows the projected trajectory of CO₂ emission under the business as usual scenario.

**Figure M-5: Projected Trajectory of CO₂ Emission in Business as Usual Scenario**

![Graph showing projected CO₂ emissions](image)

**Fuel and capital costs**

We estimate the costs of the business as usual scenario by analyzing the fuel costs and the capital expenditure required to meet demand in this scenario.

Figure M-6 illustrates the projected fuel and capital costs in this scenario, with fuel costs clearly representing a larger cost over the next 20 years than the capital costs of new generation. The NPV of the fuel cost is US$2,648.3 million, the NPV of the expenditures on thermal capacity is US$150.7 million, and the NPV of the expenditures on renewable capacity is US$15.6 million, giving a total of US$2,814.6 million.
Percentage of energy generated by renewable sources

The Government of Barbados has set targets to generate 10 percent of electricity from renewable sources by 2012, and 20 percent by 2026. Figure M-7 shows the percentage of energy that will be generated from renewable sources in the business as usual scenario. Neither of the Government targets would be achieved under this scenario.

Figure M-7: Proportion of Energy Generated from Renewable Sources in Business as Usual Scenario
M.3 High Renewable Energy Scenario

The high renewable energy scenario is used to demonstrate the cost and benefits of investing in renewable energy. Investment in renewable energy will reduce BL&P’s fuel consumption and therefore CO₂ emission as well as reducing investment in peak generation. We would expect these outcomes to result from there being insufficient incentives for investment in energy efficiency, but there being sufficient incentives for investment in renewable energy, either from government policies or from market conditions.

In the reminder of this section, we present:

- Scenario-specific assumptions
- Projected demand
- Projected supply
- Sector outcomes for CO₂ emissions, fuel costs and capital expenditure, and the proportion of energy generated from renewable sources.

Scenario-specific assumptions

In addition to the general assumptions described in Section M.1, we have made the following specific assumptions in the high renewable energy scenario:

- **Demand:** With no incentives to invest in energy efficiency, demand growth for high renewable energy scenario is the same as business as usual scenario. This implies that total energy consumption per customer will grow at historical rate for all three categories of customers. The overall consumption will grow at around 2.55 percent per year.

- **Supply:** With incentives to build additional renewable generation capacity, all renewable resources that are identified in the sustainable energy matrix are utilized in this scenario. New thermal capacity is commissioned to ensure the reserve capacity margin calculated based on firm capacity is above 20 percent and demand growth is met.

Projected demand

Figure M-8 illustrates projected electricity demand in the high renewable energy scenario. The level of demand is identical to the projected demand in the business as usual scenario.
Projected supply

Figure H-9 lists the new generation investment that will need to be made to meet forecast energy demand and maintain an adequate reserve capacity margin. The new plants commissioned in a particular year are listed at the top of each bar, and decommissioned plants are listed in parenthesis. The timing of renewable generation is detailed in the sustainable energy matrix in Section 4.2.
Figure M-9: Projected Generation Expansion Plan in High RE Scenario

Note: Plants listed in () are decommissioned in that year

Figure M-10 shows the energy generated by plant type over the next 20 years in the high renewable energy scenario. Generation plants are operated on least-cost basis with renewable energy dispatched whenever available. Energy generated from medium speed diesels increases gradually as new plants are commissioned, replacing generation from low speed diesel. Steam plants will be phased out from the system in 2012 and generation from gas turbines remains relatively steady.

Figure M-10: Energy Generated by Plant Type in High RE Scenario
Relevant Results

Our projections of demand and supply enable the following results to be calculated for the high renewable efficiency scenario:

- CO₂ emissions
- Fuel costs and capital expenditure
- Proportion of energy generated by renewable sources

CO₂ emissions

In 2009, BL&P produced 832,000 tCO₂ from electricity generation. Under the business as usual scenario, the annual CO₂ emissions will decrease sharply between 2011 and 2014 to around 663,000 tCO₂, as the result of aggressive investment in renewable energy, and decommissioning relative CO₂ intensive steam generating plants. Emissions remain flat until 2018 and are projected to resume a growth trend after 2018 because new thermal generation plants are needed to meet demand as available renewable energy resources are fully utilized. In 2029, we expect BL&P to produce just over 919,000 tCO₂ under high renewable energy scenario. Figure M-11 shows the projected trajectory of CO₂ emission under the high renewable energy scenario.

Figure M-11: Projected Trajectory of CO₂ Emission in High RE Scenario

Fuel and capital costs

We estimate the costs of the high renewable energy scenario by analyzing the fuel costs and the capital expenditure required to meet demand in this scenario. Figure M-12 illustrates the projected fuel and capital costs in this scenario, with fuel costs clearly representing a larger cost over the next 20 years than the capital costs of new generation. The NPV of the fuel cost is US$2,450 million, the NPV of the expenditure on thermal capacity is US$104.1 million, and the NPV of the expenditure on renewable capacity is US$233.3, giving a total of US$2,788.0 million.
**Percentage of energy generated by renewable sources**

The Government of Barbados has set targets to generate 10 percent of electricity from renewable sources by 2012, and 20 percent by 2026. Figure M-13 shows the percentage of energy that will be generated from renewable sources in high energy efficiency. Both Government targets would be exceeded under this scenario.

**Figure M-13: Proportion of Energy Generated from Renewable Sources in High RE Scenario**
M.4 High EE Scenario

This high energy efficiency scenario is used to demonstrate the cost and benefits of investing in energy efficiency. Investment in energy efficiency reduces the overall energy consumption and peak demand. Reduction in energy consumption reduces the BL&P’s fuel consumption and therefore CO₂ emissions. A reduction in peak demand enables BL&P to delay its investment in new capacity in the short term and reduce capital expenditure in the long term. We would expect these outcomes to result from there being insufficient incentives for renewable energy investment, but there being sufficient incentives for energy efficiency, either from government policies or from market conditions.

In the reminder of this section, we present:

- Scenario-specific assumptions
- Projected demand
- Projected supply
- Sector outcomes for CO₂ emissions, fuel costs and capital expenditure, and the proportion of energy generated from renewable sources.

Scenario-specific Assumptions

In addition to the general assumptions described in Section M.1, we have made the following assumptions for high energy efficiency scenario:

- **Demand:** Residential, commercial, and industrial consumers invest in economically-feasible energy efficiency appliances identified in the sustainable energy matrix. As a result, growth in average consumption per customer falls from
  - 2.11 percent to 0.79 percent for residential customers, resulting in an overall reduction of 24.9 percent over 20 years
  - -0.92 percent to -2.11 percent for commercial customers, resulting in an overall reduction of 22.4 percent over 20 years
  - -1.95 percent to -2.61 percent for industrial customers, resulting in an overall reduction of 11.32 percent in 20 years.

The overall growth in energy consumption reduces from 2.14 percent to 0.97 percent per year, and growth in peak demand reduces from 2.18 percent to 1.05 percent.

- **Supply:** The assumption for supply under high energy efficiency scenario is identical to business as usual scenario. With no incentives to build additional renewable generation capacity, BL&P will build the thermal plants currently in its capital expenditure plan, followed by a mix of more thermal plants.

Projected demand

Figure M-14 illustrates projected electricity demand in high energy efficiency scenario. Demand from commercial customers remains a relatively constant portion of total demand. Most of the growth in demand comes from residential customers. The share of electricity demand from residential customers is projected to grow from 32 percent to around 40
percent of total consumption. Peak demand is shown by the line in Figure M-14 and reaches 220MW by 2029.

**Figure M-14: Projected Demand in High EE Scenario**

Projected supply

Figure M-15 lists the new generation investment that will need to be made to meet forecast energy demand and maintain an adequate reserve capacity margin. The new plants commissioned in a particular year are listed at the top of each bar, and decommissioned plants are listed in parenthesis.
Figure M-15: Projected Generation Expansion Plan in High EE Scenario

Note: Plants listed in ( ) are decommissioned in that year

Figure M-16 shows the energy generated by plant type over the next 20 years in the business as usual scenario. Generation plants are operated on a least-cost basis with renewable energy dispatched whenever available. Energy generated from medium speed diesels increases gradually as new plants are commissioned, replacing generation from low speed diesel. Steam plants will be phased out from the system in 2012 and generation from gas turbines remains relatively steady.

Figure M-16: Energy Generated by Plant Type in High EE Scenario
Relevant Results

Our projections of demand and supply enable the following results to be calculated for the high energy efficiency scenario:

- CO₂ emissions
- Fuel costs and capital expenditure
- Proportion of energy generated by renewable sources

**CO₂ emissions**

In 2008, BL&P produced 832,000 tCO₂ from electricity generation. Under the business as usual scenario, the annual CO₂ emissions will decrease briefly between 2011 and 2013 to around 757,000 tCO₂, as the result of decommissioning relative CO₂ intensive steam generating plants, adding Lamberts wind farm, and the investments in energy efficiency. CO₂ emissions then remain relatively constant from 2013 to 2018, and from 2020 to 2029, with growth experienced between 2018 and 2020. In 2029, we expect BL&P to produce just over 931,000 tCO₂ under high energy efficiency scenario.

Figure M-17 shows the projected trajectory of CO₂ emissions under the high energy efficiency scenario.

**Figure M-17: Projected Trajectory of CO₂ Emission in High EE Scenario**

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**Fuel and capital costs**

We estimate the costs of the high energy efficiency scenario by analyzing the fuel costs and the capital expenditure required to meet demand in this scenario. The figure below illustrates the projected fuel and capital costs in this scenario, with fuel costs clearly representing a larger cost over the next 20 years than the capital costs of new generation. The NPV of the fuel cost is US$2,486.6 million, the NPV of the expenditure on thermal capacity is US$99.2 million, the NPV of the expenditure on renewable capacity is US$14.7 million, and the NPV of the expenditure on energy efficiency is US$234.1, giving a total of US$2834.7 million.
The Government of Barbados has set targets to generate 10 percent of electricity from renewable sources by 2012, and 20 percent by 2026. Figure M-19 shows the percentage of energy that will be generated from renewable sources in high energy efficiency. Neither of the Government targets would be achieved under this scenario.

**Figure M-19: Proportion of Energy Generated from Renewable Sources in High EE Scenario**

Energy generated from renewable sources are short of government target in both 2012 and 2016
M.5 Sustainable Energy Scenario

The sustainable energy scenario is used to demonstrate the cost and benefits of investing in both energy efficiency and renewable energy. In this scenario we assume BL&P invests in all the renewable generation options before commissioning more thermal generation capacity to meet demand growth. Consumers invest in additional energy efficient appliances and equipment. Investment in both renewable energy and energy efficiency reduces the overall energy consumption and peak demand, the fuel consumption and CO₂ emissions. A reduction in peak demand also enables BL&P to delay its investment in new capacity in the short term and reduce capital expenditure in the long term. We would expect these outcomes to result from there being sufficient incentives for both renewable energy investment, and for energy efficiency, either from government policies or from favorable market conditions.

In the reminder of this section, we present:

- Scenario-specific assumptions
- Projected demand
- Projected supply
- Sector outcomes for CO₂ emissions, fuel costs and capital expenditure, and the proportion of energy generated from renewable sources.

Assumptions

In addition to the general assumptions described in Section M.1, we have made the following assumptions for high energy efficiency scenario:

- **Demand:** The assumption for demand growth under sustainable energy scenario is the same as the assumptions made for high energy efficiency scenario. Residential, commercial and industrial consumers invest in economically-feasible energy efficiency appliances identified in the sustainable energy matrix. The overall grow in energy consumption reduces from 2.14 percent to 0.97 percent per year, and growth in peak demand reduces from 2.18 percent to 1.05 percent.

- **Supply:** The assumption for supply under sustainable energy scenario is the same as high renewable energy scenario. With incentives to build additional renewable generation capacity, all renewable resources that are identified in the sustainable energy matrix are utilized in this scenario. New thermal capacity is commissioned to ensure the reserve capacity margin calculated based on firm capacity is above 20 percent and annual demand is met.

Projected demand

Figure M-20 illustrates projected electricity demand in high sustainable energy scenario. The level of demand is identical to the projected demand in the high energy efficiency scenario.
Figure M-20: Projected Demand in Sustainable Energy Scenario

Projected supply

Figure M-21 lists the new generation investment that will need to be made to meet forecast energy demand and maintain an adequate reserve capacity margin. The new plants commissioned in a particular year are listed at the top of each bar, and decommissioned plants are listed in parenthesis. The timing of renewable generation is as detailed in the sustainable energy matrix in Section 4.2.
Figure M-21: Projected Generation Expansion Plan in Sustainable Energy Scenario

Figure M-22 shows the energy generated by plant type over the next 20 years in the high renewable energy scenario. Generation plants are operated on least-cost basis with renewable energy dispatched whenever available. Energy generated from medium speed diesel increases gradually as new plants are commissioned, replacing generation from low speed diesel. Steam plants will phased out from the system in 2012 and generation from gas turbines remains relatively steady.

Figure M-22: Energy Generated by Plant Type: High Sustainable Energy Scenario
Relevant Results

Our projections of demand and supply enable the following results to be calculated for the high sustainable renewable scenario:

- CO₂ emissions
- Fuel costs and capital expenditure
- Proportion of energy generated by renewable sources

**CO₂ emissions**

In 2008, BL&P produced 832,000 tCO₂ from electricity generation. Under the business as usual scenario, the annual CO₂ emissions will decrease sharply between 2011 and 2018 to around 573,000 tCO₂, as the result of aggressive investment in renewable energy, investments in energy efficiency, and decommissioning relative CO₂ intensive steam generating plants. CO₂ emissions will increase between 2018 and 2020 before stabilizing around 659,000 tCO₂. Figure M-23 shows the projected trajectory of CO₂ emissions under the sustainable energy scenario.

**Figure M-23: Projected Trajectory of CO₂ Emission in Sustainable Energy Scenario**

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**Fuel and capital costs**

We estimate the costs of the high renewable energy scenario by analyzing the fuel costs and the capital expenditure required to meet demand in this scenario. Figure M-24 illustrates the projected fuel and capital costs in this scenario, with fuel costs clearly representing a larger cost over the next 20 years than the capital costs of new generation. The NPV of the fuel cost is US$1,979.3 million, the NPV of the expenditure on thermal capacity is US$84.9 million, the NPV of the expenditure on renewable capacity is US$233.3 million, and the NPV of the expenditure on energy efficiency is US$234.1, giving a total of US$2,531.6 million.
**Percentage of energy generated by renewable sources**

The Government of Barbados has set targets to generate 10 percent of electricity from renewable sources by 2012, and 20 percent by 2026. Figure M-25 shows the percentage of energy that will be generated from renewable sources in high energy efficiency. Both Government targets would be well achieved under this scenario.

**Figure M-25: Proportion of Energy Generated from Renewable Sources in High Sustainable Energy Scenario**
Appendix N: Institutional Capabilities Assessment

While some progress has been made in the national planning process for sustainable development in the energy sector, a number of factors continue to hinder this process. These factors include:

- Lack of legal authority and institutional capacity in the sector, which are integral to implementation and enforcement of policies
- The challenge of communicating sustainable energy development concepts to the general public
- Lack of timely reviews and evaluation of the planning process, leading to needs that are often overlooked
- Lack of financial and human resources.

In the implementation and monitoring of the SEF, the bulk of the work will fall to the following key institutions:

- The Energy Division of the Ministry of Finance, Investment, Telecommunications and Energy (MFIE)
- The Government Electrical Engineering Department (GEED)
- The Town and Country Development Planning Office (TCDPO)
- The Fair Trading Commission (FTC); and,
- The Barbados Light and Power Company (BL&P).

It is therefore be necessary to determine whether these institutions are well suited to deliver the required outputs given their location within the governmental bureaucracy and in the private sector, and also to determine whether they have sufficient capacity to undertake the required tasks. Below we review the functions and capabilities of these institutions.

N.1 The Energy Division of MFIE

The Energy Division was established in 1978 to monitor developments in the energy sector and movements in petroleum prices. Since that time, the Division has expanded its functions and has turned into an organization responsible for oil and gas, alternative energy, energy conservation, and the provision of geological and earth science services to other Government departments and the private sector.

The Division is charged with monitoring energy price movements; liaising with the Caribbean Community (CARICOM) Secretariat and the Latin America Energy Organization (OLADE, or Organización Latinoamericana de Energía) on regional energy issues; preparing submissions to Cabinet, and papers to reflect the position of Government on energy, geological, and earth science-related matters in various fora. The Division is also responsible for monitoring the Barbados National Oil Company Limited (BNOCL), the agency responsible for exploration, production and procurement of oil and gas; the Barbados National Terminal Company Limited (BNTCL), which is responsible for the terminal logistics and storage of oil products and crude oil; and the National Petroleum Corporation (NPC), which distributes the gas produced by BNOCL.
The Energy Division is comprised of an Administrative Unit; a Legal and Regulatory Unit; the Natural Resources Department; the Renewable Energy and Energy Conservation Unit; and the Research and Planning Unit. An organization chart that also shows the functional teams that operate within the Division is shown in Figure N-1 below.

**Figure N-1: Organization Chart of MFITE Energy Division**

The above organization structure of MFIE can best be described as a “matrix organization structure” because it is based on both horizontal and vertical relationships between different teams. Matrix management involves multiple employee reporting structures as indicated by the arrows in the organization chart in Figure N-1. It emphasizes both vertical organizational hierarchy and horizontal interrelationships. Employees within a matrix organization report both upwards to superiors and, based on project requirements, may also report sideways to peers. The matrix structure is well suited to the mission of MFIE, as it seems that most activities of this Ministry are carried out as management of separate projects. This structure has the potential of adapting well to teams working on several different projects and processes. However, the arrangements appear to have placed insufficient focus on the need to develop energy efficiency and renewable energy as quickly as possible, particularly given the present demands of the SEF.

Interviews with staff have indicated that over the years there has not been a sustained effort to build capacity in the Renewable Energy Unit, and that there is a large staff turnover. Hard numbers are not available to verify the turnover rate. However, as an example, it was
reported that the Unit failed to retain every Technical Officer recruited since the 1980s.\textsuperscript{34} By way of comparison, it was also reported that the staff that has been involved with the fossil fuel activities of the Energy Division has remained relatively stable over the same period, with a very low turnover rate.

The RE unit has very little data collection capabilities as far as international benchmarking is concerned, and has to rely mainly on data collected by OLADE. Difficulty has also been reported in accessing the budgetary resources needed to establish a national database of energy information. At the present time, no data on production, consumption, storage and trade are collected and analyzed. Energy accounts and balances are also not prepared in a way that would cover all flows of energy and allow more informed decision making for the sector. The parameters for the comprehensive database have been established, but the paucity of staff prevents this from being implemented. The Division anticipates that stakeholder participation in the data collection process will be required in any event in order for the exercise to be successful. It is anticipated that a Memorandum of Understanding (MOU) will be developed to govern the relationships between the Energy Division and the several stakeholders that it is proposed will be involved in the data collection process.

The Program Document for Financial Years 2010-2013 concurs with the above analysis, as it notes under the section “Energy Information” that “there is a pressing need for information on energy at the national, regional and global levels for planning and programming purposes. The procedures for collecting and evaluating this data will be enhanced.” The Program Document also proposes that the traditional linkages with regional energy agencies, such as the Caribbean Energy Information System (CEIS) in Jamaica and OLADE in South America, will have to be augmented with information from emerging focal points such as the CARICOM Energy Desk in Guyana and the International Energy Agency in Paris.\textsuperscript{35}

Between 2010 and 2013, the Ministry plans to continue the following activities:

1. Review energy information from both national and international sources as a basis for planning and decision making
2. Continue the further development and full implementation of the OLADE and CEIS energy systems that were commenced in fiscal year 2009/2010
3. Prepare geospatial maps of key energy resource sites in Barbados (oil, wells, wind farms, mines, and others).

Given the above program of activities for the years 2010 to 2013, it is difficult to see how this will be accomplished with the limited staff that is available. The matrix organization structure would allow tasks to be assigned to ad-hoc teams within the organization. However, the capabilities and interest in RE development that would be required for the successful implementation of the SEF do not appear to reside outside of the existing RE Team. Further, the structure demonstrates a relative lack of recognition of the importance of RE in the overall energy mix.

To ensure the effective implementation of the SEF it will be necessary to ensure that:

- RE is given a higher priority in the activities of the ED

\textsuperscript{34} The most recent loss of a Technical Officer took place in March 2010.

\textsuperscript{35} The staff of the Energy Division reports that Barbados is not currently a member of the International Energy Agency.
- The implementation program is coordinated across all of the institutions involved in its implementation, a task that clearly falls to the Energy Division.

N.2 Town and Country Development Planning Office (TCDPO)

In order for approvals to be obtained for the development of RE projects, it will be necessary for the proponents of RE projects to seek and obtain the approval of the Town and Country Development Planning Office (TCDPO) before any construction involving material modification to building structures can take place. The Town and Country Planning Act (Chapter 240 of the Laws of Barbados) makes provision for Building Preservation Orders at Section 28(1). This Section provides that if it appears to the Minister that it is expedient to make provision for the preservation of any building of special architectural or historic interest in the island, the Minister may for that purpose make an order restricting the demolition, alteration, or extension of the building.

The staff of the TCDPO only specializes in town planning. The Chief Town Planner (CTP), who has the final responsibility for approving applications, is therefore required to consult with various other government agencies before approvals can be granted, and relies extensively on their advice. Thus, although the department effectively grants the approvals for developments and alterations to building structures, the TCDPO relies on other government agencies (such as the Grantley Adams International Airport Authority) if the proposed development is to take place in the airport zone.

Section 8 of the Town and Country Planning Act gives the CTP wide powers to consult with whoever he chooses and, during the approval of proposals for alterations or additions to any development plan, to consult such persons or bodies as he sees fit. For example, where environmental impacts are expected, the CTP will ensure that applications are accompanied by an assessment of the impact that the development is likely to have on the environment of Barbados.

The extent to which additional capacity will be required at the TCDPO to handle expected applications for RE developments will therefore depend to a large extent on how rigorously the CTP interprets his mandate.

N.3 Government Electrical Engineering Department (GEED)

The GEED is responsible for electrical inspections of all buildings and other electrical installations in Barbados. The Department is primarily concerned with the safety aspects of such electrical installations. RE installations will be required to comply with the same safety standards that other electrical installations are required to conform to.

The Chief Electrical Officer (CEO) himself has had formal training and experience in installing the few such systems that have been installed in Barbados, and has personally inspected and approved those systems that have so far been installed in the country. However, the present staff does not have the training or experience required to be able to properly assess and inspect RE systems and as a result they will require additional training.

The CEO does not anticipate that the department will need additional staff to cope with the expected demand for inspections from the public as the increase is expected to be very small, particularly during the pilot phase. Additional training will, however, be required. Castalia concurs with this assessment.
N.4 Barbados Light and Power Company (BL&P)

In an effort to promote efficiency in the use of energy and the use of renewable energy, BL&P proposed in its last rate case submitted to the FTC the introduction of a new Time-of-Use (TOU) tariff, an Interruptible Service Rider (ISR), and a Renewable Energy Rider (RER) for small grid-connected renewable energy systems. BL&P has also proposed that the TOU tariff and the two riders should be implemented on a pilot basis for a period of 3 years before deciding whether those schemes should be implemented permanently. The FTC approved the pilot rates for a period of 2 years starting on 1 July 2010.

Based on the FTC’s approval, BL&P will need to prepare for the interconnection of small, customer-owned solar photovoltaic systems into the grid. These units, generally less than 5 kW in size, are designed to connect directly to a customer’s electrical panel and offset the amount of electricity required from the grid, with any excess feeding back into the grid.

BL&P has already prepared draft interconnection agreements that detail the specifications and minimum standards required for interconnection with customers wishing to connect renewable energy devices to the grid. BL&P does not expect to increase its staff to be able to cope with installations during the pilot phase of the project, and will use the opportunity of the pilot to determine if any additional staff will be required if it is determined that the programme will continue after the 3-year pilot phase. However, it notes that the Government Electrical Engineer will be required to inspect all such installations as they will constitute a material variation of the original installation and therefore to be re-inspected. It also expects that an additional meter will be required to be installed to measure the energy being supplied to the grid from the RE source.

Castalia concurs with the assessment by BL&P and agrees that no additional staff will be required during the pilot phase, as the expected rate of installation and the additional work that will be involved in making each of these connections will be negligible.

N.5 The Fair Trading Commission (FTC)

Among its other functions, the FTC is required to enforce the Utilities Regulation Act. These functions are set out in Section 4(1) of the Act, which requires the FTC to “enforce the Utilities Regulation Act and any laws relating to consumer protection and fair competition which the Commission has jurisdiction to administer”. Specifically, in relation to the regulation of public utilities, the Act requires the Commission to:

- Establish principles for arriving at the rates to be charged by service providers
- Set and monitor the maximum rates to be charged by service providers
- Determine and monitor the standards of service applicable to service providers
- Carry out periodic reviews of the rates and the principles by which they are set, as well as the standards of service supplied by service providers
- Hear and determine complaints by consumers regarding billings and the standards of service supplied by service providers.

Having approved the implementation of the Rider for RE, it is not anticipated that the FTC will need to carry out any further analysis with respect to the operation and interconnection of small, customer owned solar photovoltaic systems into the grid. We therefore do not believe that the FTC will need to increase its capacity to analyze and monitor the
performance of RE projects, as what little monitoring and analysis that will take place can be accommodated within the current structures and staffing levels. In any event, it is expected that the FTC would be able to rely on the data produced by the Energy Division of MFIE, particularly if the capacity in this department is augmented.

The FTC currently has an Electricity Analyst in place to review the reports submitted by BL&P to the FTC each month. This task is expected to fully occupy the Analyst and it is not expected that there would be sufficient spare capacity to undertake the tasks associated with reviewing or advising on licence applications. Another staff member, an electrical engineer or an individual qualified in renewable energy engineering, would therefore be needed to review applications, prepare draft licences, and/or advise the minister on the grant of such licences. However, the rate at which applications will be forthcoming for RE licences is largely unknown at the present time. The situation should therefore be monitored and, if warranted, an additional staff member could be recruited to undertake the reviews and to prepare reports advising the minister concerning licences.

In carrying out the tasks related to reviewing least-cost expansion plan or avoided cost calculations submitted by BL&P, outsourcing would be the best option for undertaking the reviews in the short to medium term. It would be unwise for the FTC to staff itself up with experienced specialist engineers and economists for handling tasks that would be needed once every two or so years.
Appendix O: Case Studies and Lessons Learnt on Sustainable Energy Financing

The Smart Fund is intended to be a sector-specific fund that will provide financial support to promote EE and RE technologies in Barbados. Financial support to specific sectors has been experimented in Barbados and other neighboring countries. Here we present a set of case studies that support the design we are recommending for the Smart Fund. The case studies show what the governments in Barbados and other countries have done to provide incentives for investing in particular sectors. The case studies we present are:

- The Promotion of Solar Water Heaters (SWH) in Barbados: this policy started in the early 1970s and consisted of a mix of fiscal and customs incentives as well as higher excise taxes on the electric water heaters
- The Student Revolving Loan Fund in Barbados: the Fund was created in the late 1970s to increase the access of low income households to tertiary education
- The Territorial Financing Institution (Financiera de Desarrollo Territorial - FINDETER) in Colombia: FINDETER is a rediscounting facility that supports loan by commercial banks to sub-national governments
- The Incentives Program for Alternative Sources of Electricity (Programa de Incentivo a Fontes Alternativas de Energia Elétrica - PROINFA) in Brazil: PROINFA provides subsidized loans for investments in power generation from renewable energy sources
- Electric Power Saving Trust Fund (Fideicomiso para el Ahorro de Energia Electrica - FIDE) in Mexico: FIDE is a trust fund created by the Government, power producers, and power sector unions to promote energy efficiency. One of its most successful initiatives is the creation of a seal for the identification of energy efficient devices.

These initiatives provide examples of innovative ways of financing and supporting specific public policies whenever markets are not efficiently organized to pursue a government’s objectives.

This appendix provides more details on each initiative. The key lessons from these initiatives that can be applied to the Smart Fund are:

- **The Smart Fund should be designed using existing instruments**—FINDETER has contributed to the creation of a dynamic sub-national market for sovereign debt in Colombia. The demand by sub-national governments for long term loans that would be used for illiquid investments, such as public infrastructure, was generally not attractive for commercial banks. FINDETER, by allowing commercial banks to rediscount their loans to sub-national governments, created the additional guarantees commercial banks needed to provide credit to sub-national governments. The Smart Fund, by providing subsidized credit for financing hire purchase schemes, will play a similar role for retailers and final consumers. The Smart Fund will support an option that is now available but not widely used for EE and RE technologies.
The Smart Fund should capitalize on the skills of existing institutions—FINDETER is a discounting facility that helps commercial banks offer their financial products to sub-national governments. PROINFA promotes investments in RE by offering subsidized loans to independent power producers. The Smart Fund would do the same by helping retailers to offer hire purchase schemes at favorable terms for EE and RE investments. Offering financing to retailers allows the Smart Fund to capitalize on the existing hire purchase schemes. Retailers have the advantage of developed skills and know how regarding the market for EE and RE equipment.

The Smart Fund’s support should make EE and RE technology accessible to a broader market: supporting hire purchase schemes will increase access to EE and RE technology by households and businesses. The Fund aims to “popularize” these new technologies. FIDE buys CFLs in bulk at lower prices and sells them to final consumers by charging them on their electricity bills. The Student Revolving Loan Fund grants student loans to low and middle income households who may otherwise be prevented from accessing tertiary education.

O.1 Promotion of Solar Water Heaters in Barbados

Policy objectives: Reduce energy consumer costs; stimulate the local Solar Water Heater (SWH) market (manufacturers/suppliers); reduce Barbados’ dependency from imported fossil fuels and enhance the country’s energy security.

Beneficiaries: homeowners, commercial and industrial businesses including SWH manufacturers.

Instruments used: Fiscal incentives and disincentives

From 1974 to 1980: SWH manufacturers and suppliers benefited from import duty exemptions for raw materials. The import duty amounted to 20 percent. The waiver reduced the final cost of installation by 5 percent to 10 percent. This measure was coupled with an additional levy on electric water heaters (30 percent). Today no additional tax is imposed on electric water heaters 36.

From 1980 to date (suspended 1992-1996): The Government introduced an additional fiscal incentive. It allows homeowners to deduct the full-cost of a SWH installation up to BB$3,500 per year. After 1996 the incentive was reintroduced as part of the homeowners’ allowance scheme. Under the scheme homeowners can deduct up to BB$10,000. Homeowners have an additional deduction of BB$5,000 a year for five years (up to BB$25,000) for “environmentally preferred products” which include SWH.

From 1974 to date the Government has purchased about 1,200 SWHs. The SWH have been installed in public buildings. The purchases have contributed to supporting the local demand for SWHs.

Financial objectives: n/a

36 Electric water heaters are subject taxation practice for imported goods. This practice includes: 20 percent customs duty, one percent environmental levy, and 15 percent Value Added Tax (VAT).
**Cost estimate:** Annual costs of SWH tax incentives have ranged from BB$ 0.2 million in the early nineties, when tax deductibility was suspended, to BB$ 1.80 million in 1989\(^{37}\) when the SWH demand peaked. The cumulative cost up to 2002 is estimated at around BB$21.5 million. The cumulative cost approximately equates the *annual* energy savings (estimate: BB$23 to BB$32 millions), calculated as the amount of kWh saved through the substitution of electric water heaters with SWH (between 65 to 92 million kWh) multiplied by the average domestic electric rate.

**Risk profile:** n/a

**Management structure:** Ministry of Finance. No *ad hoc* entity or body.

**Brief history:** Promotion of SWHs started in 1974 with the Fiscal Incentive Act. The Act granted import preferences and tax holidays to the SWH industry. The energy crisis of the period was the main driver behind the act. The personal interest in the technology by the then Prime Minister Tom Adams has contributed to the support and implementation of the policy.

**Brief evaluation:** As a result of the incentives, SWHs are widely used in Barbados today as opposed to many other Caribbean countries where penetration is limited. In Barbados SWHs are estimated to cover about 40 percent of the households. This means that over 1 household every three uses solar energy to heat the water. The total number of installed SWH is estimated around 35,000 units. 80 percent of these are installed in residential buildings.

The policy has also contributed to the creation of a local industry. Sixty percent of the heaters are produced locally by three manufacturers, Solar Dynamics, SunPower and AquaSol.

**Sources**


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**O.2 Student Revolving Loan Fund in Barbados**

**Policy objective:** Provide loans for tertiary education at preferred rates.

**Beneficiaries:** Low income students

The Fund lends directly to individual students. Requirements for obtaining loans include two grantors of age included between 21 and 55 and with a minimum annual income of BB$16,000 for loans up to BB$30,000 and an annual income of BB$28,000 for loans above BB$30,000 up to BB$50,000. Currently the Student Revolving Loan Fund (SRLF) has 4,000 outstanding loans.

\(^{37}\) The paper does not specify if the figure is in nominal or real terms and what is the base year if deflated.
**Instruments used:** Subsidized loans

The SRLF finances loans at a subsidized interest rate. The maximum amount of loans is BB$ 50,000. The interest rate is 6 percent. The repayment period cannot be extended beyond 12 years after the grace period. The grace period is up to one year after completion of study. Loans can cover courses in four categories: graduate, undergraduate, post secondary/technical education, and vocational education. Loans can be used for local, regional and extra regional institutions.

**Financial objectives:** the financial objective is to preserve the fund capital indefinitely.

Student loans are financed with receipts from previous loans. Administration costs are covered by Government transfers of approximately BB$ 2.5 million per year.

Despite the default rate is around 25 percent, the Fund claims to be financially self-sustained. This means that loan repayments and interest payments are enough to cover the lending activity despite one lender every four is not servicing the dept.

**Cost estimate:** Official cost estimate for the Fund are not available. However, the information presented so far hint that costs are most likely above BB$ 2.5 millions. The amount corresponds to government transfers that the Fund uses to cover administrative costs.

**Risk profile:** the Fund is assuming 100 percent of the lending risk involved in the activity

**Management Structure:** the Fund is an agency within the Ministry of Education and Human Resource Development that directly disburses funds to students.

**Brief History:** The Fund was created in 1976. For the first 20 years (until 1996) it has relied on loans from IADB to survive. It has also considerably expanded the scope of action, from funding undergraduate education, to graduate and educational courses. The maximum amount of loans has gone from 30,000 to 50,000 Barbadian dollars.

**Brief evaluation:** The Fund has recently commissioned a survey to evaluate its impact. Results of the studies are not publicly available, but the Fund’s portal highlights the following results:

- Over 75 percent of the graduates find a job within six months from graduation
- 53.5 percent of the graduates earn more than BB$48,000 a year
- 73.4 percent of the respondents are satisfied with their job
- About the half of the respondents (47.2 percent) of the respondents say they were unlikely to attend university without the loan.

**Sources**

http://www.srlfloan.edu.bb/

http://www.mes.gov.bb/

Email response from the Fund Administrative Manager, Roslyn Shepherd
O.3 Territorial Financing Institution (FINDETER) in Colombia

Policy objective: Increase access to financing to local governments. Build capacity at the local level by helping local governments gaining borrowing experience

Beneficiaries: commercial banks and sub-national governments

FINDETER lends money to commercial banks enabling them to provide affordable loans to local governments. Financiera de Desarrollo Territorial (FINDETER) has signed agreements with 32 first-tier banks over the last 10 years. Only two of them have gone bankrupt over this period, and both defaulted in 2000, amid the economic crisis.

In more recent years FINDETER has broaden the customer base from local municipalities to service companies. In 2003 these represented the 51 percent of the customer base for loans backed by FINDETER

Instruments used: FINDETER discounts long-term loans to commercial banks.

Initially the loan rate provided by participating banks to their clients was capped at 5 percent above the market average of fixed-term deposits. FINDETER was initially discounting the loans at a rate equal to the market average plus 2.5 percent. This was allowing a spread of up to 2.5 percent to commercial banks. However, commercial banks were able to offer more attractive loans since the early 90ies even without FINDETER backing.

In 2004 FINDETER was able to offer refinancing on loans of 6 years or more for an interest rate of 800 basis points over the Fixed Deposit Rate, an index of bank deposit rates. FINDETER discounts the loans a 650-700 basis points over the Fixed Deposit Rate.

Risk profile: FINDETER is second-tier lender.

Commercial banks bear 100 percent of the risk. The mechanism is the following:

1. The commercial bank writes a loan to the sub-national government entity
2. FINDETER authorizes the transaction
3. After the loan is signed, the commercial bank can rediscount the loan at FINDETER
4. The relation between the commercial bank and the local government is not altered by the rediscounting operation. The commercial bank is responsible to FINDETER for servicing the discounted loan.

FINDETER has a very safe risk management. It maintains an equity-to-total funding ratio of around 40 percent (on average): Colombian law sets the requirements at 9 percent.

Financial objectives: financial sustainability of the facility in the medium term.

In the long-term the facility should cease to exist. This will be possible when the market for investment loans is well developed at the sub-national level.

Cost estimate: n/a

Management structure: FINDETER is a legally independent and quasi-public financial institution. It is a central government agency. A minority share (8.5 percent) is owned by local governments (departments).
The agency’s headquarter is in Bogotá. There are 10 regional branches. The staff counts approximately 120 members (reduced from about 180 members). The efficiency of the facility has been criticized because of the high loan processing time. After reaching a peak of 18 months, the average processing time is now between six to eight months. In 2003 FINDETER approved an automatic process of approval (that applies only to loans below $2.6 million dollars) that speeded up the process. The procedure has been applied to about two-third of the loans.

**Brief history:** FINDETER is part of the effort made by the Colombian government to decentralize the governance structure of the country. Since the early nineties departments have become more dependent on revenue transfer but they also gained more power to collect their own resources. FINDETER is the agency the Government put in place to increase local government capacity in long-term borrowing.

When the program was launched commercial banks lack of experience for lending to sub-national governments. By rediscounting loans, FINDETER allow bridging the experience gap between commercial banks and local governments.

**Brief evaluation:** Since its creation in 1990, FINDETER has financed about US$2 billion. The loans have supported over 700 municipalities.

FINDETER has achieved an AAA credit rating and its revenues cover about 80 percent of the current refinancing activities. Financing from International Financial Institutions has dropped to 5 percent in 2003 from almost 37 percent in 1994.

FINDETER has not been able so far to expand its capital base through domestic markets. Outstanding bonds in 2003 were equal to 0.003 percent of total liabilities.

**Sources**

Kehew, Robert, Matsukawa, Tomoko and John Petersen. “Local Financing for Sub-Sovereign Infrastructure in Developing Countries: Case Studies of Innovative Domestic Credit Enhancement Entities and Techniques.” The World Bank, 2005.

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**O.4 Incentives Program for Alternative Sources of Electricity (PROINFA) in Brazil**

**Policy objectives:** Promote the expansion of power generation through renewable sources

**Beneficiaries:** Independent power producers

**Instruments used:** Preferential loans and pre-fixed rates to renewable energy generators

Incentives and subsidies are financed through an increase on energy bills (low-income sectors are exempt from this increase) that are transferred to the Energy Development Account. The Banco Nacional de Desenvolvimento Econômico e Social (BNDES, the Brazilian National Development Bank) has special financing programs available for renewables projects carried out by Independent Power Producers (IPP) that are eligible for PROINFA. BNDES can finance up to 80 percent of capital costs excluding site acquisition and imported goods and services) at the basic national interest rates (TJLP) plus

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38 The first version of the law capped the share to 70 percent
2 percent of basic spread and up to 1.5 percent of risk spread. Interests are not charged during construction and amortization is of 10 years. Payments are due 6 months after commercial operation.

Eletrobrás is the major power utility in Brazil. Under the PROINFA rules, Electrobrás buys energy at preferential prices (the “economic values” set by the Government) and markets renewable electricity. Definitive “economic values” have a reference value floor of 70 percent of the national average supply tariff. Contracts between Electrobrás and the “renewable” generators are valid for a period of 20 years, are applicable to plants that began production before 2007.

Financial objectives: n/a

Cost estimate: n/a

Management structure: The government agency supervising PROINFA is the Ministry of Mines and Energy. PROINFA is supported by the federal government through the national development bank (BNDES) for the distribution of preferred loans, and through Electrobrás for the commercialization of the generated electricity.

In December 2004 several Brazilian pension funds and banks launched an Equity Investment Fund (Brasil Energia) of 250 million US dollar to support PROINFA’s stage 1.

Brief history: The Brazilian Parliament approved the Program of Incentives for Alternative Electricity Sources (Programa de Incentivo a Fontes Alternativas de Energia Elétrica-PROINFA) in April 2002. The PROINFA program was to be implemented in two stages: stage 1 aimed to bring 3,300 MW of renewable energy (from wind, biomass and small hydroelectric sources) on stream before the end of 2007; and stage 2 targeted and increase in the share of electricity produced by three renewable sources to 10 percent of annual consumption within 20 years. At stage 2 renewable generators would be required, before December 30th of each year, to issue a number of Renewable Energy Certificates proportional to the amount of clean energy produced by the plant. ANEEL, the Brazilian power regulator, authorized the funding of stage 2 in early 2009. The allocated funds were 1.57 billion reais, the equivalent of 665million US dollar.

Brief evaluation: The target for stage 1 was reached in 2005.

Sources
International Energy Agency
http://www.iea.org/textbase/pm/?mode=re&id=1474&action=detail
on changes for financing terms

O.5 Electric Power Saving Trust Fund (FIDE) in Mexico
Policy objectives: Implement energy efficiency measures
Beneficiaries: individual consumers and commercial and industrial businesses
Instruments used: Electric Power Saving Trust Fund (Fideicomiso para el Ahorro de Energía Eléctrica —FIDE) operates through several policy initiatives:

- **FIDE Seal:** The FIDE seal helps final users identifying products with outstanding electric energy saving properties. The seal is a voluntary identification of products which have been proven to have exceptionally low levels of energy consumption. They are further proven to have a high reliability and quality. The seal has been given to 6 different types of applications: (i) Electric motors; (ii) Illumination equipment Compact Fluorescent Lamps (CFL); (iii) Domestic applications like refrigerators, air conditioning, washing machines; (iv) Water pumping systems; (v) Energy saving equipment like motion detectors; and (vi) Air compressors.

  FIDE buys equipment in bulks, which keeps the price low, and re-sells it to end-users for the same price. Final consumers can buy up to eight lamps and the price of the lamps is deducted on the electricity bills without interest in the following eight months. The contract further specifies a warranty of two years on each lamp.

- **Financial incentives for commercial and industrial users:** FIDE offers financial incentives for companies that buy equipment that carry the FIDE seal. The rebate is an in-mail one: buyers receive a coupon from the distributor or manufacturer and send it to FIDE, together with a copy of the last electricity bill. FIDE then writes out a check which is deposited in the bank account of the equipment user. FIDE also supports company that implement energy efficiency measures. FIDE gives credits without interest for energy efficiency measures that cover up to 60 percent of the total project costs. Repayment of the financed amount has to happen within 2 years without interest.

- **Education and capacity building:** These initiatives include: (i) The dissemination of information through publications, radio and TV advertisements, and participation with stands to popular events; (ii) Educational programs in museums and other cultural gatherings; (iii) Organization of seminars and other learning events.

**Risk profile:** n/a

**Financial objectives:** FIDE is a non-profit organization established to promote efficient energy use in the country. The organization is supported by public funds and private funds.

**Cost estimate:** n/a

**Management structure:** FIDE is a Trustfund financed by the Mexican Government with the participation of industry representatives (CFE) and the energy sector workers’ trade union (SUTREM). It is a non profit organization in charge of the implementation of research and policies developed by the National Commission for Energy Efficiency (Comisión Nacional para el Uso Eficiente de la Energía—CONUEE, previously CONAE). The technical committee includes members of electric utilities and industry associations.

**Brief history:** At the end of the 1980s Mexico experienced a sharp increase in the demand for energy. In 1985, 55 percent of the extracted oil was exported, in 1992 only 14 percent. The Government wanted to prevent the major source of its revenue from being depleted by internal consumption. The creation of the National Commission for Energy Savings (Comisión Nacional para el Ahorro de Energía—CONAE) in 1989 was the first action to prevent
the trend. FIDE was created at the same time as implementing agency for the research and policies developed by CONAE (today CONUEE, see above). FIDE has also participated in technical assistance programs on energy efficiency in countries in Latin America, like Costa Rica, El Salvador and Argentina.

**Brief evaluation:** N/A

**Sources**

International Solar Energy Society:
http://www.ises.org/sepcoww/Pages/CounryCaseStudyMX/5.html

Fidecomiso para el Ahorro de Energía Electrica: http://www.fide.org.mx/
Appendix P: SEF Pilot Program


Supporting Excel spreadsheets prepared by Castalia for each of the technologies to be implemented under the SEF Pilot Program—Solar PV, Wind, CFLs, and Power Monitors—and summary spreadsheet for the entire Program, November 2010.
Appendix Q: Environmental Impact Assessment for Compact Fluorescent Lamps Disposal
